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ABSTRACT

We study optimal bailout policies amidst banking and sovereign crises. Our model features sovereign borrowing with limited commitment, where domestic banks hold government debt and extend credit to the private sector. Bank capital shocks can trigger banking crises, prompting the government to consider extending guarantees over bank assets. This poses a trade-off: Larger bailouts relax financial frictions and increase output, but increase fiscal needs and default risk (creating a 'diabolic loop'). Optimal bailouts exhibit clear properties. The fraction of banking losses the bailouts cover is (i) decreasing in government debt; (ii) increasing in aggregate productivity; and (iii) increasing in the severity of banking crises. Even though bailouts mitigate the adverse effects of banking crises, the economy is ex ante better off without bailouts: Having access to bailouts lowers the cost of defaults, which in turn increases the default frequency, and reduces the levels of debt, output, and consumption.

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1 Introduction

Recent European debt crises highlighted the ‘diabolic loop’ between sovereign risk and bank risk. On the one hand, the Irish bailout of 2008 illustrated how bailouts and asset guarantees can shift financial risk to the government (Acharya et al., 2014). On the other hand, the Greek debt crisis of 2012 showed how sovereign risk can weaken banks’ balance sheets due to overexposure to government debt (Sosa-Padilla, 2018). In the presence of this diabolic loop, how much—if at all—should the government intervene to ‘save’ the domestic banking sector during banking crises?

To answer this question, we build a quantitative model that features a rich interaction between sovereign and banking risk. To mitigate the adverse effects of banking crises, which reduce credit to the private sector and thereby decrease output, the government may find it optimal to bail out banks. Bailouts come with a trade-off, boosting liquidity and output during banking crises while increasing sovereign debt and default risk. Sovereign defaults weaken banks’ balance sheets, completing the ‘diabolic loop.’ In this environment, we find it optimal—from an ex ante perspective—to ban bailouts. Absent bailouts, the diabolic loop is weakened, and this consideration dominates the ex post benefits of bailing banks out.

We model bailouts as contingent guarantees over bank capital. This is guided by empirical evidence from the recent European sovereign debt crisis. In Section 2, we document that the issuance of sovereign guarantees is the most prevalent form of intervention during banking crises. Among European countries, the average share of government guarantees relative to GDP is three times larger than the average share of direct capital transfers during banking crises—a relationship that does not hold during normal times.

Every period, the economy observes the realization of a productivity shock and a bank capital shock, which represents the fraction of bank capital that could become lost if a banking crisis materialized. In response, the government chooses the amount of potential capital losses to guarantee. These guarantees (bailouts) are financed with a mix of new borrowing and distortionary taxation. The government lacks commitment to repay, and if it should default, it temporarily loses access to new borrowing and cannot extend bailouts.

We calibrate our model using data from European countries facing sovereign risk. Our model matches salient moments in the data, both targeted and untargeted. We show that the occurrence of a banking crisis increases the default probability (from 0.5 to 0.7 percent annually), resulting in sovereign spreads that are higher (from 0.7 to 0.9 percent) and more volatile (from 0.6 to 1.0 percent). From an ex post perspective, the government finds it optimal to issue bailouts (i.e. contingent guarantees) that are on average 1.7 percent of

GDP during banking crises.

We further validate the model by comparing its dynamics around banking crises with the data. We find that banking crises are associated with sharp output contractions and sovereign yield spikes. Furthermore, governments that experience a banking crisis with high debt levels face deeper and longer recessionary dynamics and higher spreads. These dynamics are consistent with the data.

Using the calibrated model, we study the ex post optimal properties of bailouts. Other things equal, the fraction of banking losses that the bailouts would cover: (i) increases with the severity of the banking crisis, because the impact of bank capital shocks is nonlinear—small shocks negligibly affect lending to the private sector, whereas large shocks can generate a severe private credit crunch absent government intervention; (ii) decreases relative to the level of government debt, since a more indebted government has less fiscal space to prop up banking sector assets; and (iii) increases with aggregate productivity, since the better the economy's overall state, the more valuable credit is and the cheaper it is to borrow to provide the guarantees.

Our model has implications for the design of institutions that govern bailouts. Is it optimal from an ex ante perspective to allow governments to bail out the banking sector, knowing that this may lead to higher default risk? We find that the costs of bailouts (higher sovereign risk) outweigh the benefits (ability to increase liquidity during banking crises). Even though the welfare gains of maintaining access to bailouts are state-contingent, we find that for the empirically relevant cases (i.e., economies with moderate to high initial debt levels), the country is better off banning bailouts altogether. This is because governments without the ability to issue bailouts face better borrowing opportunities ex ante.

Why does ruling out bailouts improve bond prices? The answer is in the default costs: An economy without bailouts endogenously features larger default costs, which in turn allows it to have higher levels of debt, output, and consumption than an economy with bailouts, on average. The endogenous default costs in our model are given by reduced liquidity (because banks' holdings of government debt become non-performing), which leads to reduced output. This reduced liquidity continues once the government regains access to credit markets (because it does so with zero debt). However, the severity of this reduced liquidity depends on whether the government has access to bailouts: If bailouts are available, the government can use them to prop up liquidity and increase output immediately after re-entering from a default. This is why access to bailouts lowers the costs of default, reduces government debt capacity and average consumption, and decreases welfare.

We show that our main findings are robust to a broad set of modeling choices and parameter values. For example, we study an extension of the model in which the government does not lose access to bailouts during default and exclusion periods. Allowing for bailouts during default and exclusion reduces the cost of default even further, leading to larger welfare losses for the bailout economy. In another extension, we depart from the standard one-period debt and allow the government to issue long-maturity debt. This amplifies the doom-loop as now changes in bond prices (even during repayment) can affect the banks' lending capacity. We also present an extension introducing an alternative, default-free savings vehicle for banks which creates a portfolio choice between government bonds and this new asset and attenuates (but does not eliminate) the productive role of government debt. We find that the ex ante sub-optimality of bailouts is robust to these and other alternative specifications.

Related literature. This paper belongs to the quantitative literature on sovereign debt and default, following the contributions of Eaton and Gersovitz (1981), Aguiar and Gopinath (2006) and Arellano (2008). Our work differs from these early papers, in that it presents a model that entails a rich interaction between the government and the financial sector to study the transmission of risks between these sectors and their implications on the real economy.

Our paper is at the intersection of two strands in the literature. The first uses dynamic quantitative models of sovereign risk to examine how the banking channel amplifies the effects of sovereign risk. The closest paper to ours is Sosa-Padilla (2018), which studies how a sovereign default affects banks' balance sheets and creates a private sector credit crunch, endogenizing output declines. Bocola (2016) studies the macroeconomic implications of increased sovereign risk in a model, where banks are exposed to government debt. His framework takes default risk as given and shows how anticipation of a default can be recessionary on its own. Perez (2015) also studies the output costs of default when domestic banks hold government debt. Public debt serves two roles in his framework: It facilitates international borrowing, and it provides liquidity to domestic banks. In addition to the bank balance sheet effects highlighted in these studies, our paper also incorporates the transmission of banking crises to sovereign crises, which these papers do not consider.[1]

The second strand of the literature to which we are especially related is the one studying the feedback loop between sovereign risk and bank risk, the so-called 'doom loop.' Acharya

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[1] The theoretical work on sovereign risk and bank fragility is vast. A branch of the literature uses stylized models of domestic and external sovereign debt in which domestic debt weakens the balance sheets of banks (e.g., Bolton and Jeanne, 2011, Gennaioli et al., 2014, Gaballo and Zetlin-Jones, 2016, and Balloch, 2016). Other papers, more quantitative in nature, explicitly consider how banks are either affected by or amplify default risk (e.g., Boz et al., 2014, Mallucci, 2015, Thaler, 2021, Abad, 2019, Coimbra, 2020, and Moretti, 2020). Without explicitly modeling banks, Arce (2022) studies how government bailouts of the private sector can lead to increased sovereign risk.

et al. (2014) model a stylized economy where bank bailouts (financed via a combination of increased taxation and increased debt issuance) can solve an underinvestment problem in the financial sector, but exacerbate another underinvestment problem in the non-financial sector. Higher debt needed to finance bailouts dilutes the value of previously issued debt, increases sovereign risk, and creates a feedback loop between bank risk and sovereign risk because banks hold government debt in their portfolios. Cooper and Nikolov (2018) and Farhi and Tirole (2018) also study the dynamic interaction between sovereign debt and the banking system and show the conditions (in their respective theoretical models) under which a bailout-induced doom loop may arise.

We borrow insights from these papers and focus on the ex ante optimal properties of bailouts using a quantitative model calibrated to recent GIIPS (Greece, Italy, Ireland, Portugal and Spain) data. We also differ from these papers in that we model bailouts as contingent guarantees over bank capital (motivated by the evidence in Section 2).

The existing literature is split on the desirability of bailouts. For example, Bianchi (2016) and Keister (2016) study bailouts, abstracting from sovereign risk, and find that bailouts can be desirable even when taking into account moral hazard consequences. Our main departure from this literature is the consideration of sovereign risk, whereby bailouts can lead to a 'doom loop.' In this environment, we find that bailouts are ex ante suboptimal for the empirically relevant states of initial debt, even in the absence of moral hazard concerns. Farhi and Tirole (2018) and Cooper and Nikolov (2018), share our prescription: If at all possible, a country is better off ruling out bank bailouts. These papers also have theories of bailout-induced diabolic loops; we differ from them in that we provide a quantitative model with a strategic default decision. Finally, there are papers that assume an exogenous level of initial debt, and therefore focus on the ex post effects of bailouts.[2]

On the policy side, various proposals have aimed at lowering the fragility of the banking sector and its exposure to sovereign risk. Examples include the implementation of eurobonds (Favero and Missale, 2012) or the creation of European Safe Bonds (Brunnermeier et al., 2017). These proposals highlight how important it is to have reliable estimates of the dynamic relationship between sovereign risk, bank fragility, and economic activity. We provide a quantification of the role that government bailouts play in these dynamics.

Finally, our paper also relates to the large literature on country bailouts, either from a central authority (such as the ECB or IMF) or from another individual country. Contributions inspired by the recent European debt crisis include Gourinchas et al. (2020), Azzimonti

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[2] For instance, Capponi et al. (2022) find that governments should bailout banks that have a high 'network centrality' and Acharya et al. (2014) derive conditions under which the ex post optimal bailout is non-zero.

and Quadrini (2023), Pancrazi et al. (2020), Roch and Uhlig (2018), and De Ferra and Mallucci (2020), among others. These authors typically focus on moral hazard concerns and (the lack of) policy coordination. We view our work as complementary to theirs since our focus is on domestic governments bailing out their own banking sector, and we abstract from moral hazard considerations.[3]

The rest of the paper is organized as follows: Section 2 summarizes the stylized facts that motivate our theoretical model. Section 3 introduces the model. Section 4 explains the calibration of the model, presents the quantitative results, and discusses the properties of the optimal policies. Section 5 discusses the optimality of bailouts. Section 6 provides a discussion of extensions and robustness. Finally, Section 7 concludes.

2 Motivating Facts

The nexus between sovereign and banking crises is not a new phenomenon, and various aspects of it have been studied previously. In this section, we highlight three features of banking and sovereign debt crises that motivate our study: *(i)* defaults and banking crises tend to happen together, *(ii)* domestic banking sectors are highly exposed to government debt and this exposure tends to be greater during crises, and *(iii)* the most prevalent form of government intervention (during banking crises) is the issuance of asset guarantees.

- *Default and Banking crises tend to happen together.* This is a well-established fact. Reinhart (2010) documents 82 banking crises, of which 70 are accompanied by sovereign defaults. Focusing on more recent data, Balteanu et al. (2011) identify 121 sovereign defaults and 131 banking crises for 117 emerging and developing countries from 1975 to 2007. Among these, they find 36 "twin crises" (defaults and banking crises). In 19 of them, a sovereign default preceded the banking crisis and in 17 the reverse occurred, suggesting that both directions of causality are likely at play.[4]

- *Banks are exposed to sovereign debt and this exposure is higher during crises.* Gennaioli et al. (2018) report an average bank exposure ratio (net credit to the government as a

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[3] Naturally, this paper is also related to the body of work on government bailouts of banks that abstracts from sovereign risk considerations. For recent examples, see Niepmann and Schmidt-Eisenlohr (2013) and Keister (2016).

[4] Another empirical study documenting this fact is the one by Borensztein and Panizza (2009). They construct an index of banking crises that includes 149 countries for the period 1975–2000. In this sample, they identify 111 banking crises (implying an unconditional probability of having a crisis equal to 2.9 percent) and 85 default episodes (unconditional default probability of 2.2 percent). When conditioned on a sovereign default episode, the probability of a banking crisis increases by a factor of 5.

fraction of bank assets) of 9.3 percent using data from both advanced and developing countries. When they focus only on defaulting countries, they find an exposure ratio of roughly 15 percent. Similarly, Abad (2019) documents that the banking sectors in Spain and Italy increased their exposure to domestic sovereign debt during the recent European debt crisis (with exposure ratios increasing by 8 percentage points).

Our own empirical contribution is to document a third motivating fact regarding how governments intervene during banking crises. Specifically,

- *Issuance of sovereign guarantees is the most prevalent form of government intervention to alleviate banking crises.* European Union governments have largely intervened in two ways—via asset guarantees and capital transfers. Using data from Eurostat, we construct the average net annual change in government guarantees and average capital transfers as a percentage of GDP in the 23 EU countries from 2007 to 2019.[5] Figure 1 shows that governments mostly rely on asset guarantees rather than capital transfers as the way to intervene during banking crises (defined following Laeven and Valencia, 2013b). We find that the average change of government guarantees as a fraction of GDP is close to 1.7 percent during banking crises, whereas it is close to zero in the overall sample. We also find that the change in capital transfers is less different across the two time periods, suggesting that transfers figure less prominently in government banking crisis intervention. In Appendix A, we show that a similar pattern holds for "contingent liabilities" (a broader definition of asset guarantees).[6]

3 Model

We extend the banking and sovereign default model of Sosa-Padilla (2018) in two dimensions: *banking crises* that are driven by exogenous shocks to bank capital in addition to the bank balance sheet effects triggered by sovereign defaults, and *government bailouts* that can mitigate a banking crisis but may trigger sovereign default crises.

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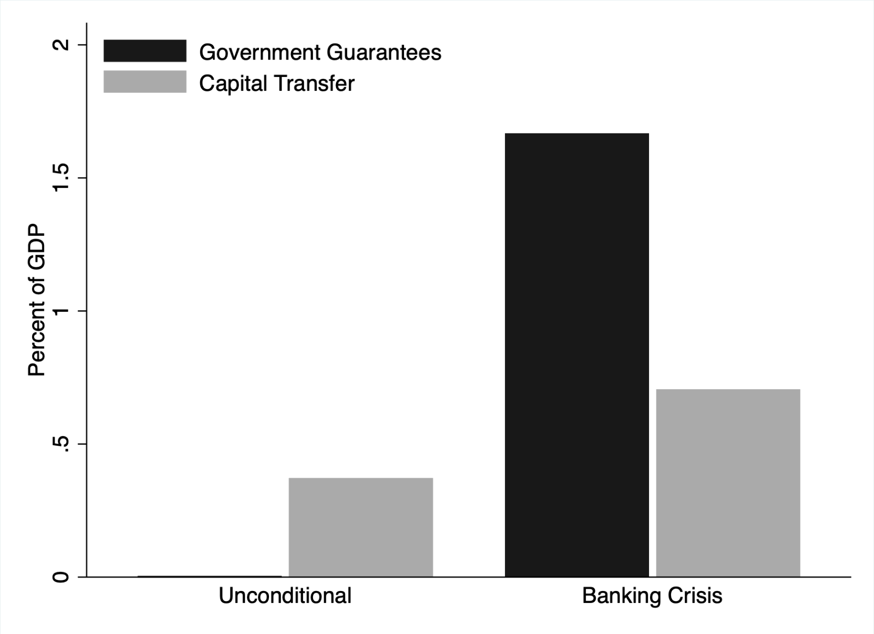
[5] The data on government guarantees and contingent liabilities are sourced from Eurostat's Government Interventions to Support Financial Institutions portal, which is accessible at: Eurostat: Government Interventions to Support Financial Institutions. See Appendix B for the details.

[6] Metrick and Schmelzing (2021) introduce a historical dataset of banking crisis interventions that covers 1257-2019. The authors show that high-income countries (with income per capita greater than 30,000 USD) favor guarantees more than capital injections as an intervention policy. Specifically, guarantees constitute 33 percent of the interventions whereas capital injections make up 26 percent of the interventions in high-income countries.

Figure 1: Government guarantees and capital transfers



Environment. We consider a closed economy populated by four agents: households, firms, banks, and a government. Households supply labor to firms, but do not face any intertemporal decisions. Firms hire labor and obtain working capital loans from banks to produce a consumption good. Banks lend to both firms and the government and are subject to a lending constraint. Additionally, banks are subject to shocks to the value of their capital. Finally, the government is a benevolent one (i.e., it maximizes households' utility). It faces an exogenous stream of spending that must be financed, and it can also provide contingent guarantees to the banks. To meet its obligations, the government has three (endogenous and potentially time-varying) instruments: labor income taxes, borrowing, and default.

Debt contracts are unenforceable, and the government may default on its debt. We assume defaults are total: All debt is erased. If the government decides to default, it gets excluded from the credit market for a random number of periods. During this time, the government cannot conduct bailouts.[7]

There are four aggregate state variables in our model economy: one endogenous and three exogenous. The level of government debt, B, is the endogenous state variable. The first exogenous state variable is aggregate productivity, z, which follows a Markov process. The second exogenous state variable, ε, captures the fraction of bank capital that could be

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[7] In Section 6 (and Appendix C.1), we relax this assumption and allow the government to issue bailouts even during default/exclusion periods. Our main result, that bailouts are ex-ante welfare decreasing, is robust to (and even strengthened by) this extension.

lost and follows an *iid* process. We denote $s = \{z, \varepsilon\}$. The third exogenous state variable, A, is the realized level of bank capital: With probability $1 - \pi$, this level is unaffected (and equal to a baseline value, $A = \overline{A}$); with probability π, it is reduced to $A = (1 - \varepsilon)\overline{A}$.

Timing of events. If the government enters the period in good credit standing, then the sequence of events is as follows:

1. The exogenous aggregate state s is realized
2. Considering the aggregate state (B, s), the government decides whether to repay ($d = 0$) or to default ($d = 1$)
3. If $d = 0$, then:
    (a) the government announces a bailout policy
    (b) given the bailout policy, banks decide their loan supply
    (c) bank capital is determined
        i. with probability π, the bank's capital is reduced by ε, and the government disburses the promised bailouts
        ii. with probability $1 - \pi$, the bank's capital is unaffected, and the government does not pay any bailouts
    (d) at the same time in which bank capital is determined, the government chooses its new borrowing B' and taxes τ, and all other private decisions occur.
4. If $d = 1$, then:
    (a) the government cannot promise bailouts and is excluded from financial markets
    (b) banks determine their loan supply
    (c) with probability π, the bank's capital is reduced by ε
    (d) all other private decisions occur.

If the government enters the period in bad credit standing (i.e. it finished the previous period excluded from financial markets), the government regains market access with probability θ. If it regains market access, then the timing of events is as above, with an initial debt level of zero. Otherwise, if the government remains excluded, the timing of events amounts to the sequence of stages 1 and 4 above.

3.1 Decision problems given government policy

Households. Households' only decisions involve labor supply and consumption levels. Therefore, the problem faced by the households can be expressed as:

$$\max_{\{c,n\}} \quad U(c,n) \tag{1}$$

$$\text{s.t. } c = (1-\tau)wn + \Pi^F, \tag{2}$$

where $U(c,n)$ is the period utility function, c stands for consumption, n denotes labor supply, w is the wage rate, τ is the labor-income tax rate, and Π^F represents the firms' profits. The solution to the problem requires:

$$-\frac{U_n}{U_c} = (1-\tau)w, \tag{3}$$

which is the usual intratemporal optimality condition equating the marginal rate of substitution between leisure and consumption to the after-tax wage rate.

Firms. Firms demand labor to produce the consumption good. They face a working capital constraint that requires them to pay upfront a certain fraction of the wage bill, which they do with intra-period bank loans. Hence, the problem is:

$$\max_{\{N,\ell^d\}} \quad \Pi^F = zF(N) - wN - r\ell^d \tag{4}$$

$$\text{s.t. } \gamma wN \leq \ell^d \tag{5}$$

where z is aggregate productivity, $F(N)$ is the production function, ℓ^d is the demand for working capital loans, r is the interest rate charged for these loans, and γ is the fraction of the wage bill that must be paid upfront.

Equation (5) is the working capital constraint. This equation will always hold with equality because firms do not need loans for anything other than paying γwN; thus, any borrowing over and above γwN would be sub-optimal. Taking this into account, we obtain the following first-order condition:

$$zF_N(N) = (1+\gamma r)w, \tag{6}$$

which equates the marginal product of labor to the marginal cost of hiring labor once the financing cost is factored in. Therefore, the optimality conditions from the firms' problem are represented by equation (5), evaluated with equality, and equation (6).

Banks. Banks play a vital role in the economy by providing loans to both the government and the firms. They face a lending constraint requiring that loans to firms do not exceed the value of their loanable resources. These resources amount to the sum of three components: b, A, and T. The first component is the banks' holdings of sovereign bonds, b. The second component is banks' capital, A, which is subject to aggregate shocks. The third component is government guarantees, $T(B, s, A)$ (i.e. the state-contingent bailouts that the government may provide).

The dynamics of bank capital are as follows: Every period, bank capital has a reference value of $\overline{A}$ that is subject to shocks, ε, which represent the fraction of bank capital that could be lost. The magnitude of the shock ε is realized at the beginning of the period, but uncertainty regarding whether the shock hits the banks is only resolved at the end of the period. With probability π, the bank's capital is reduced by a fraction ε, and with probability $1 - \pi$, the bank's capital is unaffected. These dynamics can be summarized as

$$A = \begin{cases} \overline{A} & \text{with probability } 1 - \pi \\ (1 - \varepsilon)\overline{A} & \text{with probability } \pi. \end{cases} \tag{7}$$

Let $\underline{A}(\varepsilon) = (1 - \varepsilon)\overline{A}$. We refer to the event that $A = \underline{A}(\varepsilon)$ and $\varepsilon > 0$ as a banking crisis.[8]

The lending constraint faced by banks is such that it must be satisfied in every possible state. This implies that in every period the supply of loans is limited by the worst-case scenario (i.e., the minimum) of the banks' loanable funds:

$$\ell^s \leq \min_{A} \{A + b + T(B, s, A)\}\,. \tag{8}$$

This constraint is intended to capture, in a stylized way, the idea that (a) increased uncertainty about the state of the banking sector can spill over into the real economy, and (b) the government can prevent banking sector shocks from causing contractions in output by

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[8] While we describe shocks to A as fluctuations in banks' capital, they could more broadly be interpreted to include: (a) domestic bank runs (as they will affect the funding side of the banks' balance sheet), (b) shocks to the valuation of holdings of foreign debt (as highlighted in Gunn and Johri, 2018), and (c) global shocks (e.g. 'sudden stops' that may be transmitted through cross-border banking networks). See Section 6 and Appendix C.8 for a discussion on the sensitivity of our results to different values of $\overline{A}$.

issuing bailouts.[9]

When the government has access to credit, the value function of the representative bank is given by

$$W^R(b;B,s) = \max_{\ell^s} \mathbb{E}_A \left\{ \begin{array}{ll} \max\limits_{x,b'} & x + \delta \mathbb{E}_{s'|s}\left[(1-d')W^R(b';B',s') + d'W^D(s')\right] \\ \text{s.t.} & x \leq T(B,s,A) + b - q(B',s)b' + r(B,s,A)\ell^s \end{array} \right\} \tag{9}$$
$$\text{s.t. } (8)$$

where x is consumption, δ is the banks' discount factor, $r(B,s,A)$ is the interest rate on private loans, $q(B',s)$ is the price of government bonds, and B', T, and d are government policies for debt, bailouts, and default, which the banks take as given. W^d is the value of the representative bank when the government does not have access to credit, and is given by

$$W^D(s) = \max_{\ell^s,x} x + \delta \mathbb{E}_{s'|s}\left[\theta W^R(0;0,s') + (1-\theta)W^D(s')\right] \tag{10}$$

$$\text{s.t. } x \leq r_{\text{def}}(s)\ell^s \tag{11}$$

$$\ell^s \leq \underline{A}(\varepsilon) \tag{12}$$

where θ is the probability that the government regains access to credit and $r_{\text{def}}(s)$ is the interest rate on private loans when the government does not have access to credit. In this case, the bank can provide loans only up to the adverse realization of its loanable funds, given by equation (12).

3.1.1 Characterization of equilibrium given government policies

Hereafter, we focus on bailout policies that take the following form:

$$\begin{cases} T = 0 & \text{if } A = \overline{A} \\ 0 \leq T \leq \varepsilon \overline{A} & \text{if } A = (1-\varepsilon)\overline{A}. \end{cases} \tag{13}$$

In other words, the government cannot provide bailouts if the adverse bank capital shock does not materialize, and it can only cover a sum not to exceed the amount of the bank's capital loss if the shock does materialize. In that sense, we also refer to the bailouts as

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[9] Our modeling assumptions imply that transfers have a one-for-one effect on bank loans. There are several papers that study how government interventions affect bank lending using micro-level data. For example, focusing on the effect of the Troubled Assets Relief Program (TARP) on bank loans, Berrospide and Edge (2010) show that a \$1 increase in capital received resulted in an increase of between \$0.4 and \$1.5 in loans over the following year. See Berger et al. (2020) for a summary of this literature.

government guarantees.

Loan market. When the government does not have access to credit, banks supply

$$\ell^s_{\text{def}}(s) = \underline{A}(\varepsilon). \tag{14}$$

When the government has access to credit, banks supply

$$\ell^s(B, s) = B + \underline{A}(\varepsilon) + T(B, s, \underline{A}(\varepsilon)). \tag{15}$$

Note that the loan supply does not depend on the realization of A. Instead, given our restrictions on government bailout policies, the total loan supply is determined by the level of government debt (B), the reduced bank capital $\underline{A}(\varepsilon)$, and government transfers T.

The demand for intra-period loans comes from the firms. Combining equations (6) and (5) (with equality) we obtain the following loan demand function:

$$\ell^d(B, s, A) = \gamma \left[\frac{znF_n}{1 + \gamma r} \right]. \tag{16}$$

Note that the loan demand depends on the realization of A. This is because during a banking crisis ($A = \underline{A}(\varepsilon)$ with $\varepsilon > 0$), the government may need to raise distortionary labor income taxes to pay for the bailouts, affecting equilibrium labor.

It is then straightforward to derive the equilibrium conditions for the loan rate under repay and default:

$$r(B, s, A) = \max \left\{ \frac{zn(B, s, A)F_n}{B + \underline{A}(\varepsilon) + T\left(B, s, \underline{A}(\varepsilon)\right)} - \frac{1}{\gamma}, 0 \right\} \tag{17}$$

and

$$r_{\text{def}}(s) = \max \left\{ \frac{zn_{\text{def}}(s)F_n}{\underline{A}(\varepsilon)} - \frac{1}{\gamma}, 0 \right\}. \tag{18}$$

As was the case in Sosa-Padilla (2018), there is the possibility that the interest rate that clears the loan market in (17) or (18) is not strictly positive. In that case, the equilibrium loan amount is demand determined. Notice that a default shrinks the supply of loanable funds and, other things equal, increases the rate on the working capital loans. This loan rate increase arises from two reasons: Bonds are not repaid, and the government is unable to extend bailouts during defaults.

Government bond market. After the proceeds from private loans are received (recall these are intra-period loans), the banks invest in government bonds before the end of the period. These bonds are the only way to transfer resources across time, and they are priced according to their inherent default risk. The bond pricing function satisfies

$$q(B';\ s) = \delta \mathbb{E}_{s'|s} \left\{ \left[1 - \underbrace{d(B', s')}_{\text{default premium}} \right] \mathbb{E}_{A'} \left[1 + \underbrace{r\left(B', s', A'\right)}_{\text{lending discount}} \right] \right\} \tag{19}$$

This expression shows that in the case of a default in the next period, $d(B', s') = 1$, the lender loses not only the original sovereign bond investment but also future gains that those bonds would have created had they been repaid. These gains are captured by $\mathbb{E}_{A'}\left[r(B', s', A')\right]$.

3.2 Determination of government policies

The government's optimization problem can be written recursively as:

$$V(B, s) = \max_{d \in \{0,1\}} \left\{ (1-d) V^R(B, s) + d\, V^D(s) \right\} \tag{20}$$

where V^R and V^D are the values of repaying and defaulting, respectively. Let $\kappa \equiv (B, s, A)$ denote the complete aggregate state and $\Phi \equiv \{\tau, T, B'\}$ summarize the fiscal policies under repay. The value of repaying is:

$$V^R(B, s) = \max_{\Phi} \mathbb{E}_A \Big\{ U\big(c\left(\kappa; \Phi\right), n\left(\kappa; \Phi\right)\big) + \beta\, \mathbb{E}_{s'|s} V\left(B', s'\right) \Big\} \tag{21}$$

subject to:

$$\tau\, w(\kappa; \Phi)\, n(\kappa; \Phi) + B'\, q(B', s) = g + B + T \qquad \text{(gov't b.c.)}$$

$$c(\kappa; \Phi) + x(\kappa; \Phi) + g = zF\left(n(\kappa; \Phi)\right) \qquad \text{(resource constraint)}$$

$$\left.\begin{array}{ll} T = 0 & \text{if } A = \overline{A} \\ 0 \leq T \leq \varepsilon \overline{A} & \text{if } A = \overline{A}(1-\varepsilon) \end{array}\right\} \quad \text{(constraint on } T\text{)}$$

and

$$\left.\begin{aligned}
&q(B',s) = \delta\, \mathbb{E}_{s'|s}\Big\{ \left[1-d(B',s')\right] \mathbb{E}_{A'}\big[1+r(\kappa';\Phi')\big]\Big\}\\
&r(\kappa;\Phi) = \max\left\{\tfrac{zn(\kappa;\Phi)F_n}{B+\underline{A}(\varepsilon)+T(\underline{A}(\varepsilon))} - \tfrac{1}{\gamma}, 0\right\}\\
&-\tfrac{U_n}{U_c} = (1-\tau)\, w\left(\kappa;\Phi\right)\\
&zF_n = \left(1+\gamma\, r\left(\kappa;\Phi\right)\right) w\left(\kappa;\Phi\right)\\
&\ell\left(\kappa;\Phi\right) = \gamma w(\kappa;\Phi) n(\kappa;\Phi)\\
&x(\kappa;\Phi) = T + B - q(B',s)B' + r(\kappa;\Phi)\ell\left(\kappa;\Phi\right)
\end{aligned}\right\}\quad \text{(comp. eq. conditions)}$$

where $c(\kappa;\Phi)$, $n(\kappa;\Phi)$, $x(\kappa;\Phi)$, $\ell(\kappa;\Phi)$, $w(\kappa;\Phi)$, $r(\kappa;\Phi)$, and $q(B',s)$ represent the equilibrium quantities and prices for the private sector given public policy (under repayment).

The value of default is:

$$V^D(s) = \max_{\tau}\ U\big(c_{\text{def}}\left(s;\tau\right), n_{\text{def}}\left(s;\tau\right)\big) + \beta\, \mathbb{E}_{s'|s}\big[\theta V\left(0,s'\right) + (1-\theta)V^D\left(s'\right)\big] \tag{22}$$

subject to:

$$\begin{aligned}
&\tau\, w_{\text{def}}(s;\tau)\, n_{\text{def}}(s;\tau) = g && \text{(gov't b.c.)}\\
&c_{\text{def}}(s;\tau) + x_{\text{def}}(s;\tau) + g = zF\left(n_{\text{def}}(s;\tau)\right) && \text{(resource constraint)}
\end{aligned}$$

$$\left.\begin{aligned}
&r_{\text{def}}(s;\tau) = \max\left\{\tfrac{zn_{\text{def}}(s;\tau)F_n}{\underline{A}(\varepsilon)} - \tfrac{1}{\gamma}, 0\right\}\\
&-\tfrac{U_n}{U_c} = (1-\tau)\, w_{\text{def}}\left(s;\tau\right)\\
&zF_n = \left(1+\gamma\, r_{\text{def}}\left(s;\tau\right)\right) w_{\text{def}}\left(s;\tau\right)\\
&\ell_{\text{def}}\left(s;\tau\right) = \gamma w_{\text{def}}(s;\tau) n_{\text{def}}(s;\tau)\\
&x_{\text{def}}(s;\tau) = r_{\text{def}}(s;\tau)\ell_{\text{def}}\left(s;\tau\right)
\end{aligned}\right\}\quad \text{(comp. eq. conditions)}$$

where $c_{\text{def}}(s;\tau)$, $n_{\text{def}}(s;\tau)$, $x_{\text{def}}(s;\tau)$, $\ell_{\text{def}}(s;\tau)$, $w_{\text{def}}(s;\tau)$, and $r_{\text{def}}(s;\tau)$ represent the equilibrium quantities and prices for the private sector given public policy (under default).

3.2.1 Equilibrium definition

A Markov-perfect equilibrium is then defined as follows:

Definition 3.1. A *Markov-perfect equilibrium* for this economy is (i) a set of value functions for the government $\{V(B,s), V^R(B,s), V^D(s)\}$; (ii) a set of government policy rules for borrowing $B'(\kappa)$, taxation $\tau(\kappa)$, bailouts $T(\kappa)$, and default $d(B,s)$; (iii) a set of decision rules and prices from the private sector under repay $\{c(\kappa;\Phi), n(\kappa;\Phi), x(\kappa;\Phi), \ell(\kappa;\Phi), w(\kappa;\Phi), r(\kappa;\Phi)\}$, and under default $\{c_{\text{def}}(s;\tau), n_{\text{def}}(s;\tau), x_{\text{def}}(s;\tau), \ell_{\text{def}}(s;\tau), w_{\text{def}}(s;\tau),\ r_{\text{def}}(s;\tau)\}$; and (iv) an equilibrium pricing function for the sovereign bond $q(B',s)$, such that:

1. Given prices and private sector decision rules, the borrowing, tax, bailout, and default rules solve the government's maximization problem in (20)–(22).
2. Given the price $q(B', s)$ and government policies, the decision rules and prices of the private sector are consistent with the competitive equilibrium.
3. The equilibrium price function satisfies equation (19).

4 Quantitative Analysis

In this section, we first describe how we set the parameters of the model. Second, we examine the ability of our model to account for salient features of the data in GIIPS countries. Third, we describe the properties of the optimal default and bailout policies.

4.1 Functional forms and stochastic processes

The period utility function of the households is given by

$$U(c,n) = \frac{\left(c - \frac{n^{\omega}}{\omega}\right)^{1-\sigma}}{1-\sigma} \tag{23}$$

where σ and ω govern risk aversion and the wage elasticity of labor supply, respectively.

The production function is given by

$$zF(n) \quad \text{with} \quad F(n) = n^{\alpha}. \tag{24}$$

We assume that TFP shocks (z) follow an AR(1) process given by:

$$\log(z_{t+1}) = \rho_z \log(z_t) + \nu_{z,t+1} \tag{25}$$

where $\nu_z \sim N(0, \sigma_z)$.

The potential bank capital shocks are assumed to take values that are between 0 and $\bar{\varepsilon}$, and have a cumulative distribution function

$$F_{\sigma_\varepsilon}(\varepsilon) = \frac{1 - \exp(\varepsilon)^{-\sigma_\varepsilon}}{1 - \exp(\bar{\varepsilon})^{-\sigma_\varepsilon}}\,, \tag{26}$$

which is a transformation of the bounded Pareto distribution. The shape parameter, σ_ε, determines the variance of the ε shocks.

4.2 Calibration

A period in the model is assumed to be a year. Table 1 presents the parameter values. Appendix B has details of the data we use to guide our calibration and Appendix D provides details of the numerical solution. Whenever possible, we use data targets computed from GIIPS. However, when appropriate, we also use an extended sample of countries that include a mix of emerging and advanced economies to compute other moments such as default and banking crisis frequencies, given that these are relatively rare occurrences.

Table 1: Parameters

Parameters	Values	Target/Source
Household discount factor, β	0.81	Default probability: 0.5 percent
Risk aversion, σ	2	Sosa-Padilla (2018)
Frisch elasticity, $\frac{1}{\omega-1}$	0.67	Sosa-Padilla (2018)
Government spending, g	0.15	Gov't consumption (percent GDP): 19.1
Prob. of financial redemption, θ	0.50	Expected exclusion: 2 years
Banks' discount factor, δ	0.96	Real interest rate: 4 percent
Baseline bank capital, $\bar{A}$	0.28	Bailouts in banking crises (percent GDP): 1.7
Bank capital shock shape, σ_ε	4.26	Standard deviation of output: 3.4 percent
Prob. of banking shock, π	0.03	Banking crisis frequency: 1.8 percent
Labor share, α	0.70	Sosa-Padilla (2018)
Working capital constraint, γ	0.52	Sosa-Padilla (2018)
TFP shock persistence, ρ_z	0.80	Standard value
TFP shock std, σ_z	0.02	Standard value

The household and government's discount factor is set to 0.81 to match a default probability of 0.5 percent. Since our analysis mainly focuses on the European periphery, our target default probability of 0.5 percent is lower than that used for emerging economies (Aguiar et al. 2016) and higher than that for advanced economies (Hur et al. 2018).[10] Government spending, g, is set to 0.15 to match the median government consumption share of GDP of 19.1 percent in GIIPS (1999–2019). The probability of financial redemption, θ, is set to 0.5, which implies an average exclusion of 2 years.[11]

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[10] The default frequency calculated for a panel of 38 advanced and emerging economies during 1970–2017 is 0.5 percent.

[11] This is a middle ground estimate given the long exclusion spells typically observed after defaults in emerging economies and the relative quick resolution of recent sovereign crises in peripheral Europe. In Appendix C, Table C.14 shows the sensitivity analysis for θ.

The bank's discount factor is set to 0.96, to be consistent with a real interest rate of 4 percent. The level of the baseline bank capital, $\overline{A}$, is set to 0.28 so that the model matches the size of bailouts during banking crises, which is 1.7 percent of GDP as shown in the empirical section. The shape parameter for shocks to bank capital, σ_ε, is set to 4.26 to generate a standard deviation of output that matches the median of 3.4 percent among GIIPS. The parameter that governs the probability of shocks to banks' capital, π, is set to 0.03 so that the model matches the banking crisis frequency of 1.8 percent in a panel of 38 advanced and emerging economies from 1970 to 2017.[12] In the data, we follow the classification in Laeven and Valencia (2013b), who use banking sector losses and other indicators to identify banking crises. In the model, we define a banking crisis as a non-zero reduction of bank's capital. This occurs with probability $\pi(1 - F_{\sigma_\varepsilon}(\underline{\varepsilon}))$ where $\underline{\varepsilon}$ refers to the lowest non-zero value in our discrete grid for ε.

Six parameters are set externally. Following Sosa-Padilla (2018), we set risk aversion, $\sigma = 2$, and set the value of ω to correspond to a Frisch elasticity of 0.67, both standard values in the literature. Also as in Sosa-Padilla (2018), we set the labor income share $\alpha = 0.7$ and the working capital constraint $\gamma = 0.52$. Finally, we set the persistence $\rho_z = 0.8$ and standard deviation $\sigma_z = 0.02$, within the range of the typical values used in the literature.[13] Appendix C presents a sensitivity analysis and shows that our main results are robust to using alternative values for key model parameters.

4.3 External validity: simulated moments

In this subsection, we examine the fit of the model. Table 2 shows the targeted and untargeted moments from our model simulations and their data counterparts. As is usual in this literature, we report statistics for periods in which the government has access to financial markets and no defaults are declared (the only exception is default frequency, for which we use all simulation periods).

The model generates spreads that behave reasonably well. The mean and the volatility of the spread are lower than in the data.[14] This is not surprising, as the Global Financial

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[12] The list of 38 advanced and emerging economies is as in Davis et al. (2016).

[13] Previous works on sovereign default with production have parameterized the productivity process in a similar way. For example, Boz et al. (2014) (in a calibration for Spain) estimate the TFP's autocorrelation to be 0.54 and impose a standard deviation of 2.6 percent; Hatchondo et al. (2022) (also calibrated to Spanish data) find annualized persistence and standard deviation estimates of 0.89 and 2 percent, respectively. Our parameterization of the TFP process (representative of GIIPS) is within these estimates.

[14] In the model, we compute sovereign spreads in our simulations as the difference between the bond's yield $(1/q)$ and the real rate implied by the bank's discount factor $(1/\delta)$. In the data, the spread is computed as the nominal interest rate on government bonds in GIIPS minus that of Germany, from 1999 to 2019.

Table 2: Simulated moments: model and data

	Model	Data
Default frequency	0.5	0.5
Banking crisis frequency	1.8	1.8
Gov't spending/GDP	19.1	19.1
Bailouts/GDP (banking crisis)	1.7	1.7
Sovereign spread		
mean	0.7	1.2
standard deviation	0.6	1.8
corr(spread, output)	–0.3	–0.6
Debt/GDP	15.5	25.8
corr(bailouts, debt)	–0.3	–0.4
Bailout-output multiplier	1.5	
Banking sector loss	25.1	21.5

Units: percent. Both the standard deviation and the correlation are calculated based on HP-filtered residuals.

Crisis and the European Sovereign Debt crises occurred during the period (1999–2019). The model also generates countercylical spreads, qualitatively consistent with the data, albeit less so than in the data. The mean debt level in the model simulations is 15.5 percent of GDP, below the median domestic government debt/GDP in EU countries, 25.8 percent.[15] Accounting for more than 50 percent of this untargeted moment is a reasonably good fit, given the well-known difficulty of sovereign default models with one-period debt in producing sizeable debt ratios at the observed default frequencies.[16]

We find that the model produces a negative correlation between government guarantees and debt. This correlation is -0.3, which is similar to the data.[17] This negative correlation highlights how higher indebtedness limits the ability of the government to issue guarantees. We return to this issue in Section 4.5, where we describe the properties of the optimal bailouts.

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[15] This median for domestic government debt is obtained using ECB data for the period 1999–2019 (including debt at all original maturities). It includes all EU countries except for the UK, Greece, Ireland, and Latvia due to missing data.

[16] The literature has dealt with this shortcoming in different ways. One example is D'Erasmo and Mendoza (2020) who study optimal domestic and external default using a one-period debt model calibrated to European data. They create a maturity-adjusted debt-to-GDP ratio and report it to be 7.45 percent of GDP. A different approach (e.g., Arellano, 2008) is to target the debt service instead of debt stock. We focus on domestic debt since we model a closed economy.

[17] Details regarding the estimation of this correlation are in Appendix B.

Our model generates a bailout-output multiplier of 1.5: a \$1 increase in bailout transfers leads to a \$1.5 increase in output. While the empirical literature is not conclusive on the magnitude (or the sign) of this multiplier, our number is very close to the multiplier of 1.6 found in a recent quantitative study on bailouts (Bianchi, 2016).[18] Our number is also close to those estimated by Faria-e Castro (2017), who finds a multiplier of 1.5 for equity injections and 2 for credit guarantees.

In the final row of Table 2, we compare the magnitude of banking crises in the model and in the data. From our model, we report the average percent of banking assets lost in a banking crisis, ${}^{\bar{A}\varepsilon}/_{(\bar{A}+b)}$, which is 25.1 percent in our simulations. For the data counterpart, we use non-performing loans as a percentage of total loans (NPL ratio) from the dataset in Ari et al. (2019), which covers crisis episodes between 1990 and 2014. We find that the average peak NPL ratio following a banking crisis is 21.5 percent in GIIPS countries, which is somewhat smaller but comparable to our model counterpart.

Banking crises vs. normal times. Table 3 shows that, conditional on experiencing a banking crisis in the previous year, the default probability is 0.2 percentage points higher than the unconditional default frequency of 0.5 percent. This increase in the default probability is the 'diabolic loop' at work: Banking crises trigger payments of contingent bailouts, and therefore, imply that governments need to borrow more. This higher level of indebtedness pushes governments into the default risk zone, leading to more frequent defaults.

Table 3: Simulated moments: unconditional and banking crisis

	Unconditional	Banking crisis
Default frequency	0.5	0.7
Sovereign spread		
mean	0.7	0.9
standard deviation	0.6	1.0
Debt/GDP	15.5	16.0
Bailout/GDP	0.9	1.7

Units: percent. The standard deviation is calculated based on HP-filtered residuals of the spread.

These 'diabolic loop' dynamics naturally translate into sovereign spreads. The unconditional mean spread is 0.7 percent, but conditional on observing a banking crisis, the mean

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[18] For example, Barucci et al. (2019) and Laeven and Valencia (2013a) show positive effects of banking sector interventions on economic outcomes, while Claessens et al. (2005) and Cecchetti et al. (2009) find that bailout policies and liquidity support are associated with negative economic outcomes.

spread increases by 0.2 percentage points. This increase reflects not only the higher likelihood of default, but also a decline in the 'lending discount'. If there is a banking crisis in period t, then a default is more likely in period $t+1$ and, hence, the lender charges a higher default premium. Additionally, if in $t+1$ the default is averted, then the interest rate on loans is lower: There is higher debt and therefore greater loan market liquidity. Thus, the sovereign bond becomes a less attractive investment for these two reasons: lower probability of repayment and, in case of repayment, lower overall return. Our simulations also generate higher spread volatility conditional on a banking crisis because default risk increases.

The last row of Table 3 shows that, on average, the model features larger contingent bailouts during banking crises than unconditionally.[19] This is a distinctive feature of the data, as we documented in Figure 1.

4.4 External validity: dynamics around banking crises

To further validate our model, we examine the behavior of output and sovereign yields around banking crises. To compute the data counterparts, we construct an annual dataset of real interest rates, GDP, government debt, and banking crisis indicators for 1950–2016, using the Jordà et al. (2017) Macrohistory database.[20]

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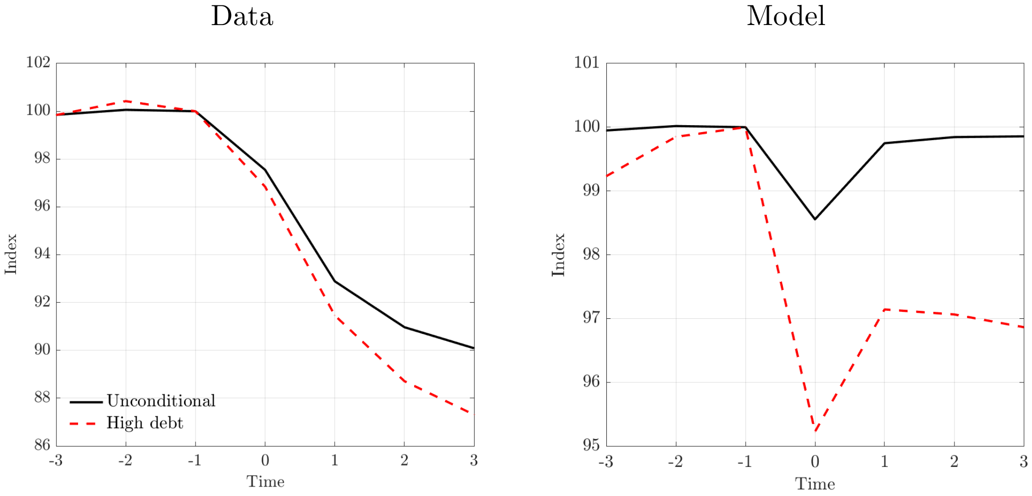
[19] Consistent with the data, here we are reporting announced bailouts (as a percent of GDP), regardless of whether a banking crisis materializes and bailout transfers are disbursed.

[20] See Appendix B for details regarding the construction of the dataset.

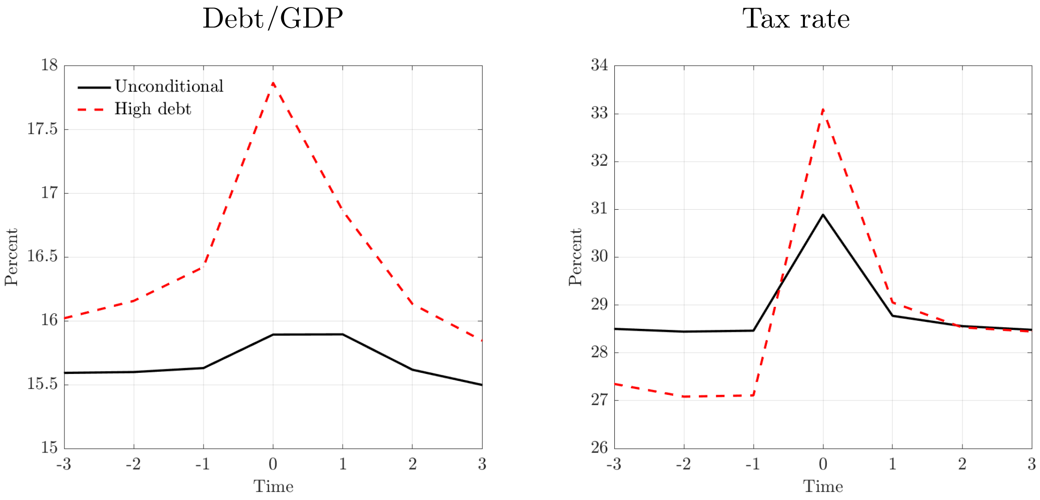
Figure 2: Output around banking crises



Note: The left and right panels show the dynamics of GDP around banking crises in the data and in the model, respectively. The red dashed line conditions on high debt (above the 75th percentile). All series in this figure are normalized to 100 in $t = -1$.

Absent government intervention, a banking crisis reduces loanable funds, increases firms' borrowing costs and decreases output. At the same time, the government can issue contingent guarantees to prop up the supply of loans and mitigate the negative effects of the shocks to bank capital. Therefore, the equilibrium response of output depends on the initial debt level: Governments with more debt (less fiscal space) face limits on the amount of bank capital losses that can be guaranteed and will, therefore, experience a larger output contraction. Figure 2 shows that this model prediction also holds qualitatively in the data. Moreover, both model and data show that banking crises occurring at high debt levels are characterized by protracted output declines. In the model, this happens for three interrelated reasons: (i) mean reversion in productivity, (ii) worsening borrowing conditions and deleveraging, and (iii) higher distortionary taxes. In this class of models, the samples identified as 'high-debt' samples are those where the economy experiences a series of good productivity realizations, which allow it to take on higher debt. This eventually is followed by a mean reversion in TFP, contributing to a decline in output. At the same time, deteriorating productivity worsens borrowing terms, to which the government responds by deleveraging.

Figure 3: Debt and taxes around banking crises



Note: The left panel shows the dynamics of Debt/GDP around banking crises and the right panel shows the dynamics of the tax rate. Both panels are for model-generated data. The red dashed line conditions on high debt (above the 75th percentile).

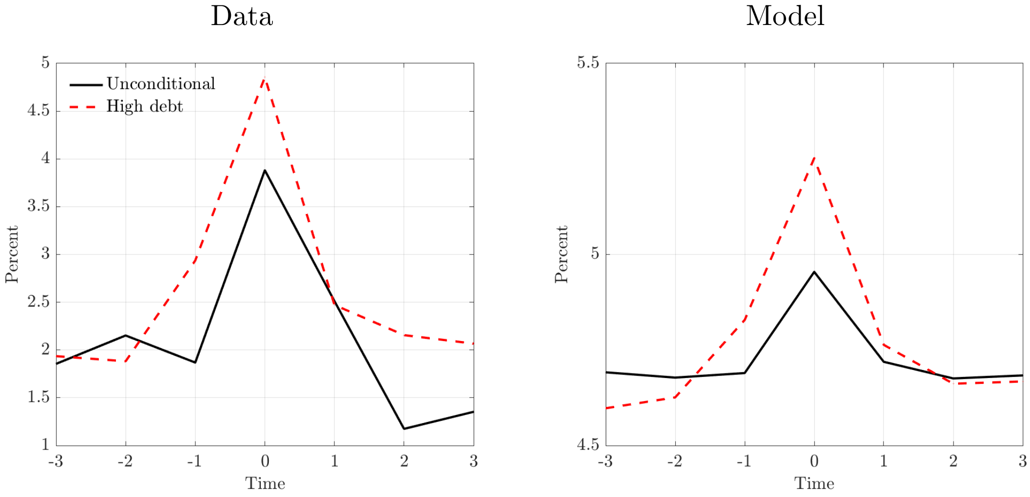
This deleveraging translates into lower liquidity in the domestic credit markets in subsequent periods, further contributing to a decline in output. Finally, to finance this deleveraging, the government raises distortionary taxes, which depresses equilibrium labor and output. These model dynamics for debt and taxes are illustrated in Figure 3.

Furthermore, our theory predicts an increase in sovereign yields during banking crises. Figure 4 shows that this model prediction is qualitatively consistent with the data. We also see that, both in the model and in the data, when the government suffers a banking crisis with high debt levels, sovereign yields are higher. For the same reasons highlighted above, the high-debt government faces worse borrowing terms, forcing the government to deleverage and increase distortionary taxes. Because the government does not want to distort the economy further, it chooses to accept higher equilibrium yields instead of deleveraging even more.

4.5 Properties of optimal policies

Default incentives, bond prices, and debt dynamics. Our model features rich interaction between debt levels, default incentives, banking crises, and bailout guarantees. Consistent with the default literature, our model also generates default incentives that decrease with the aggregate level of productivity and increase with debt, which can be verified in the left panel of Figure 5. In addition to this standard finding, we also see that the de-

Figure 4: Sovereign yields around banking crises

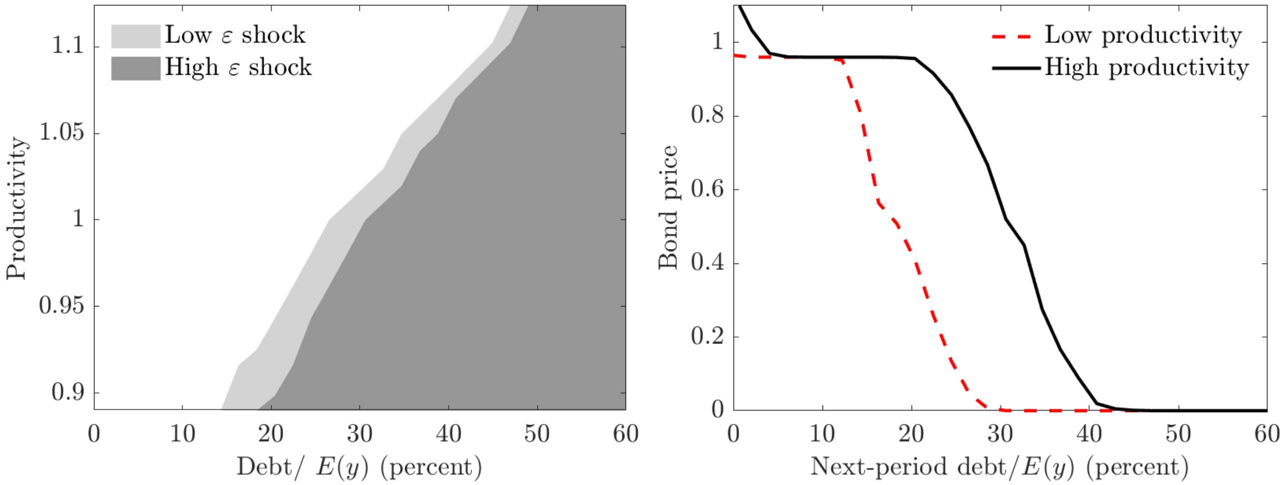


Note: The left and right panels show the dynamics of sovereign yields around banking crises in the data and in the model, respectively. The red dashed line conditions on high debt (above the 75th percentile).

fault set shrinks with higher values of the bank capital shock. This is because severe banking crises can lead to sharp contractions in output absent government bailouts, thus increasing the cost of default.

The price schedule (right-panel of Figure 5) reflects these default incentives. As usual, higher realizations of productivity are associated with better prices (and higher debt capacity). The price schedule demonstrates that borrowing is essentially risk-free for debt ratios below 12 percent. Consequently, starting from zero debt, the economy's debt-to-GDP ratio quickly increases until it reaches 12 percent. It then 'lives' in the region where default risk is small but positive, as in Figure 6, which plots the histograms of debt-to-GDP ratios both unconditionally and conditional on banking crises. Since the left tails of these histograms are very long, we choose to truncate them in our plots.

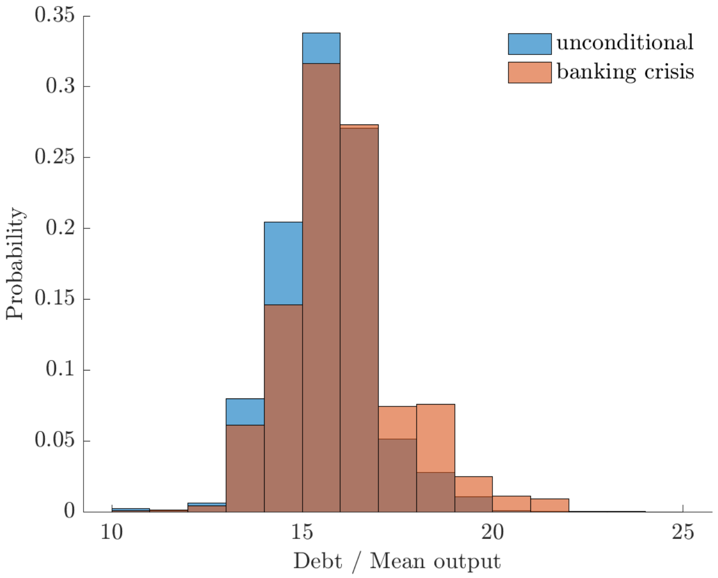
Figure 5: Default sets and bond prices



Note: The left panel shows the default sets with the shaded areas indicating default and the white area indicating repayment. The right panel shows the equilibrium bond price schedule.

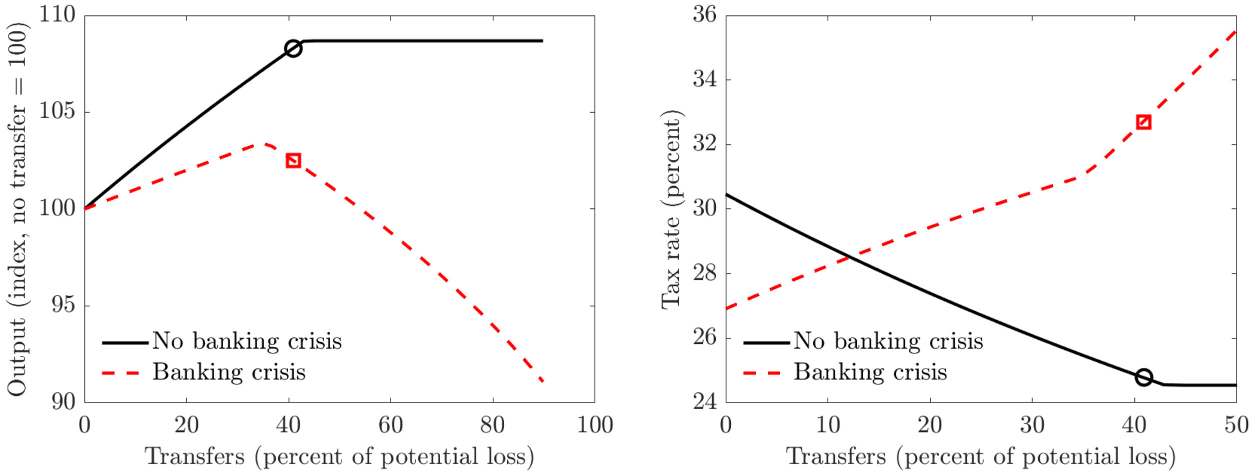
Figure 6 also shows that the debt-to-GDP distribution conditional on a banking crisis is more skewed to the left than the unconditional distribution. Thus, not only do banking crises lead to a higher average debt-to-GDP ratio (Table 3), but they also increase the probability of observing high debt-to-GDP realizations (greater than 20 percent), reinforcing the 'diabolic loop' dynamics.

Figure 6: Conditional and unconditional debt distributions



Tradeoffs faced when choosing the bailouts. What are the trade-offs that the planner is considering when choosing the promised bailout level? On the one hand, a higher $T(\cdot)$ supports credit and output. On the other hand, higher transfers may require either higher taxes (and therefore higher distortions) or higher debt (which increases default risk).

Figure 7: The effect of bailouts on output and taxes



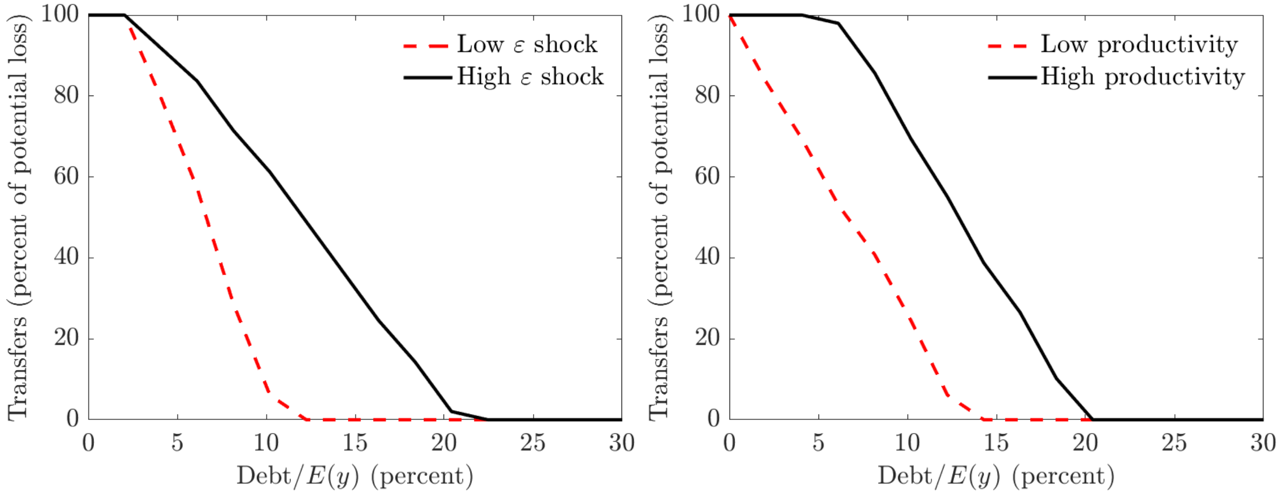
Note: The left and right panels show output and the labor tax rate, respectively, as functions of the proportional transfer (in percent of the potential loss). The markers denote the optimal choice of bailouts, which is decided prior to the realization of the banking crisis. The graph assumes that next-period debt is chosen optimally. The solid black line is for the case in which the banking crisis does not occur and the dashed red line is for the case in which it does.

Figure 7 illustrates this tradeoff. Output initially increases with the transfer, but it shows a differential behavior depending on whether the banking crisis materializes. If there is no banking crisis, then output is weakly increasing in the transfer: It increases monotonically up to the point at which there is enough credit to make the borrowing cost for the firms zero and after that point larger transfers have no further impact on output. On the other hand, if the banking crisis occurs, then output is non-monotonic in the transfer: It initially increases, but at around 40% (of the potential loss) it starts to decrease with the size of the transfer. This is because when the banking crisis happens, larger bailout payments require higher debt and/or higher taxes to finance them. For very large bailouts, the required higher taxes are sufficiently distorting and lead to lower output.

As mentioned above, the behavior of taxes is important for this tradeoff. The right panel in Figure 7 shows the tax rate function for different candidate values of the bailout (assuming that the debt is optimally chosen). If a banking crisis does not happen, then the promised bailouts come "at no cost" – credit and output get propped up but since the impact on bank capital doesn't materialize the actual fiscal budget improves, allowing the government to reduce taxes. However, if the banking crisis occurs, then the bailouts need to be disbursed and these are financed partly with taxes.

Optimal bailout policies. The ability of the government to issue bailouts depends on the state of the economy in terms of productivity (z) and potential losses to bank capital (ε), in addition to the existing level of debt (B). Here we examine the bailout policy functions generated by our model to highlight the role of each of these factors. Figure 8 shows the bailout policy functions expressed as the percent of the potential loss that the government promises to guarantee. Inspecting both panels of this figure, we find the following properties for the bailouts:

Figure 8: Bailout policy



Note: The panels show the bailout policy functions expressed as the percent of the potential loss that the government promises to guarantee (i.e. $100 \times T(B, s, A)/\left(\bar{A}\varepsilon\right)$).

1. **Increasing in** ε**.** As the potential loss to bank capital increases, the proportional bailout the government chooses grows larger. This is because the impact of financial shocks on the economy are non-linear. As can be seen in equation (17), absent government bailouts, higher values of ε have a disproportionately larger effect on r than lower values of ε (i.e., ε affects r in a convex manner). Thus, the government uses bailout transfers to affect the supply side of the loan market, keeping the equilibrium interest rate low, especially when the financial shocks are large.

2. **Decreasing in** B**.** While bailout guarantees play an essential role alleviating the effects of banking crises on the real sector by boosting liquidity, increased default risk

makes it more difficult for government to provide transfers as the debt level rises. This is because when the banking crisis occurs, the bailouts will need to be financed with more borrowing. Therefore, the greater the stock of initial debt, the less fiscal space the government has to extend asset guarantees.

3. **Increasing in z.** This intuitive property is due to two forces that move in the same direction. First, with greater productivity, credit becomes more valuable. Therefore, it makes sense for the government to extend larger guarantees in good times. Second, the cost of borrowing necessary to finance a bailout is lower during periods of high productivity. Given the persistence of productivity shocks, a high productivity shock during this period increases the likelihood of a high productivity shock in the subsequent period, leading to lower default risk, better prices for the government, and greater borrowing capacity to finance the bailout transfers.

5 On the Optimality of Bailouts

As explained in the previous section, bailouts come with a trade-off. They allow the government to boost liquidity and output during banking crises but they also increase debt and default risk (i.e., there is a 'diabolic-loop'). Having described the properties of our model and the equilibrium bailout policies, we proceed to ask: Are bailouts desirable?

To answer this normative question, we proceed in two steps. First, we solve a no-bailout version of our model and compare its simulated moments to those in the baseline model. We show that the baseline economy sustains less debt at higher borrowing costs. This suggests that, from an ex ante perspective, allowing discretionary bailouts may not be optimal. Thus, as a second step, we solve for alternative versions of the model in which bailouts are allowed but are restricted in size, nesting both the baseline (with unrestricted bailouts) and the no-bailout models. We find that when initial debt is very low, governments prefer unrestricted access to bailouts. However, when governments begin with moderate to high levels of debt, banning bailouts altogether is beneficial. We find these results remarkable since our analysis abstracts from moral hazard concerns, a well-studied reason for which bailouts might be undesirable from an ex-ante perspective. We show that the welfare consequences are large.

We first contrast the baseline economy with bailouts to the no-bailout economy. Table 4 shows that the baseline economy exhibits higher default risk, higher and more volatile spreads, and a lower debt-to-GDP ratio. These statistics reflect that the baseline economy faces worse borrowing terms: It can sustain less debt at higher rates. The table also shows that banking crises lead to higher debt, spreads, and default in the baseline model but not in the model without bailouts, demonstrating the importance of bailouts in contributing to the diabolic loop. The last row of Table 4 reports the welfare effect of bailouts, evaluated at the simulated mean debt level.[21] We find that access to bailouts results in a welfare *loss*, equivalent to a 1.5 percent reduction in permanent consumption, relative to the no-bailout economy.

Table 4: Simulated moments comparison

	Baseline model		Model without bailouts	
	Unconditional	Banking crisis	Unconditional	Banking crisis
Default frequency	0.5*	0.7	0.3	0.3
Sovereign spread				
mean	0.7	0.9	0.5	0.5
standard deviation	0.6	1.0	0.5	0.5
Debt/GDP	15.5	16.0	26.9	26.9
Mean lending rate	0.0	0.0	0.2	0.3
Welfare gain of bailouts	–1.5			

Units: percent. * denotes targeted moments.

We next examine, from an ex ante perspective, what restrictions a country should optimally impose on the size of the bailouts. To do so, we modify the constraint on $T(B, s, A)$ as follows:

$$\left.\begin{array}{ll} T = 0 & \text{if } A = \overline{A} \\ 0 \leq T \leq \min\{\varepsilon\overline{A}, \phi\overline{\varepsilon}\overline{A}\} & \text{if } A = (1-\varepsilon)\,\overline{A} \end{array}\right\} \quad \text{(new constraint on } T\text{)}$$

where $\overline{\varepsilon}\,\overline{A}$ corresponds to the largest possible financial shock and $\phi \in [0, 1]$. Setting $\phi = 0$ corresponds to the model with no bailouts and $\phi = 1$ corresponds to the baseline model.

With this modified framework, we compute the ex ante welfare-maximizing levels of ϕ for different levels of initial debt, B_0. First, we solve for $\Lambda(B_0; \phi)$, the permanent increase in

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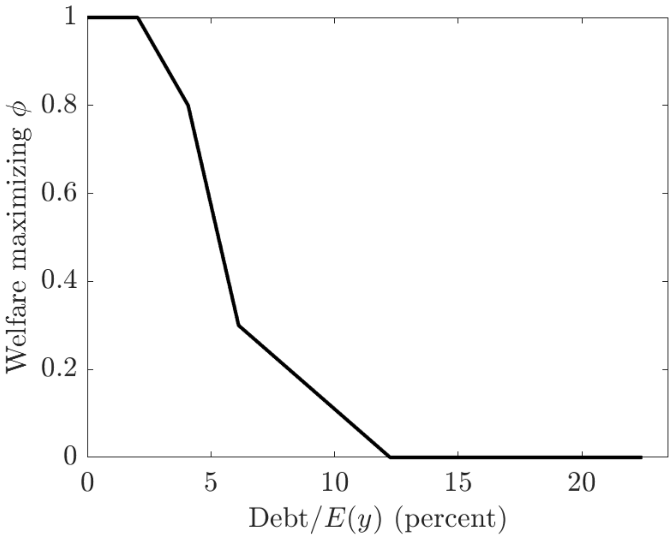
[21] We calculate welfare using consumption equivalence. For each state (B, s), we compute the value, $1 + \Delta(B, s)$, by which consumption of both households and banks—under no bailouts—would have to be permanently increased in order to make the planner indifferent to gaining access to bailouts (bank consumption only matters when the planner puts a positive weight on bank welfare, as explored in Appendix C.2). Negative values of $\Delta(B, s)$ indicate a welfare loss from bailouts. We then integrate across the ergodic distribution over s, and report the welfare loss evaluated at B which corresponds to the simulated mean of debt in the bailout economy.

Figure 9: Optimal bailout restrictions



consumption needed in the no-bailout economy to make households indifferent between this economy and another with $\phi > 0$. Formally, $\Lambda(B_0; \phi)$ is implicitly defined by

$$\mathbb{E}_s V_\Lambda(B_0, s; 0) = \mathbb{E}_s V(B_0, s; \phi) \tag{27}$$

where the expectation is taken over the ergodic distribution over $s = \{z, \varepsilon\}$ and $V_\Lambda(B_0, s; 0)$ is the value resulting from a permanent increase in consumption Λ in the economy without bailouts. Second, for each initial debt level, we compute the welfare maximizing value of ϕ.

Figure 9 shows three regions. For very low levels of initial debt, the economy is better off with unrestricted bailouts ($\phi = 1$)—that is, it is optimal to allow the government to issue bailouts that can fully cover even the largest shocks to bank capital. For intermediate debt levels, it is optimal to restrict considerably the governments' ability to issue bailouts. Finally, for debt levels exceeding 13 percent of mean output, it is welfare increasing to set $\phi = 0$—banning the government from issuing bailouts. What are the welfare consequences of instituting the optimal restrictions on bailouts? As reported in Table 4, when a government's initial debt-to-GDP level is at 15.5 percent of GDP—the mean in the simulations—access to unrestricted bailouts results in a 1.5 percent welfare *loss* relative to no bailouts, a large welfare consequence.

Intuition. To gain more intuition of the forces behind our welfare result (that bailouts are ex-ante undesirable), we study the debt-price menus faced by the economy with unrestricted bailouts and by the no-bailout economy.

Figure 10: Bond prices with and without bailouts

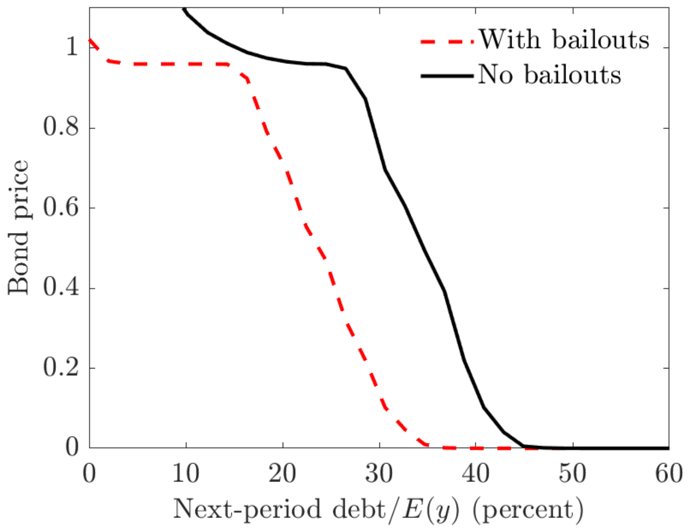


Figure 10 clearly shows that the no-bailout economy faces a more favorable price schedule. As it is usual in this class of models, the optimal policies imply that the model *lives* most of the time in the region where the price function is about to begin its steep decline. Therefore, it follows that the no-bailout economy can sustain much higher debt (26.8% vs. 15.5%) at slightly lower spreads (0.5% vs. 0.7%).

Why does the no-bailout economy face better prices? The answer is in the default costs: the no-bailout economy endogenously has larger default costs, which in turn allows it to have higher levels of debt, output, and consumption than the bailout economy, on average. What are the costs of defaults in our model? When the government defaults on its debt, it triggers a credit contraction, an increase in the borrowing costs of firms, and a decrease in output. We can think of the costs of defaults as made of two parts. The *first part* materializes in the periods in which the government is excluded.[22] In these periods, large realizations of ε are particularly damaging: There is no debt, and therefore liquidity and output are low to begin with—financial shocks make credit very scarce and output very low. This *first part* of the cost is the same for the economies with and without bailouts.[23]

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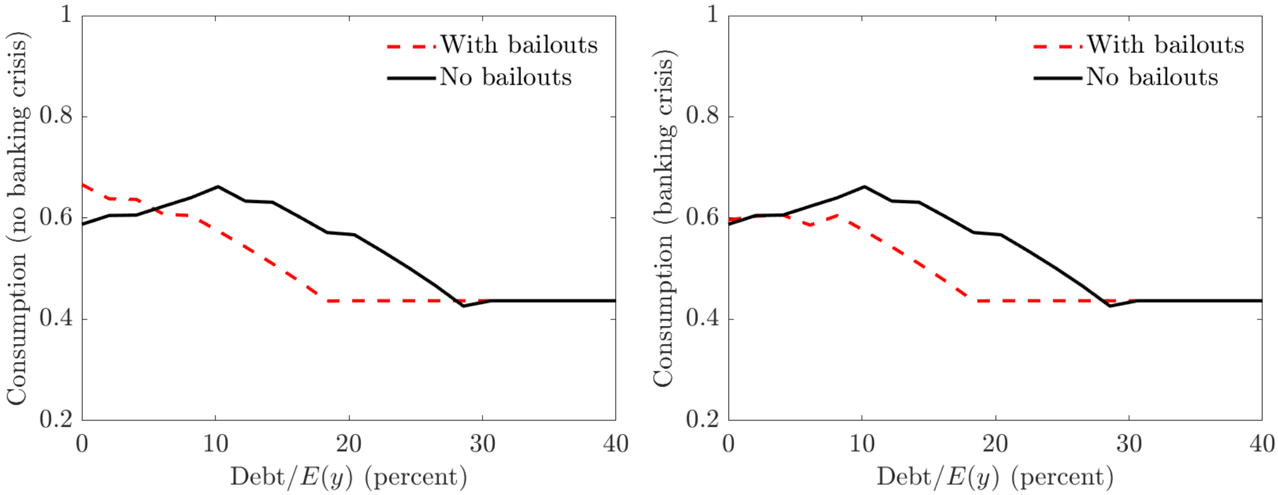
[22] Recall that the exclusion periods include the period of the default plus subsequent periods until financial redemption occurs (with probability θ).

[23] The assumption of no bailouts during exclusion is in part responsible for this feature. In Appendix C, we relax this assumption and allow the government to issue bailouts even while excluded. In line with the intuition presented here, we find that the two economies (with and without bailouts) are now even more dissimilar. After recalibrating the model to match the same targeted moments as in Section 4.2, the welfare result strengthens: Access to unrestricted bailouts results in a 2.3 percent welfare loss relative to no bailouts (when evaluated at the mean debt level in the simulations).

The *second part* comes once the government has reentered financial markets. Since debt is totally repudiated in a default, the reentry to financial markets occurs with zero debt. We can interpret the reduced output level (due to less liquidity stemming from low debt) in the early periods after reentry as another component of the costs of defaults. In these early periods after reentry, large ε shocks are also particularly damaging, but there is a difference between the bailout and no-bailout economies: The bailout economy suffers less because it can prop up liquidity using bailouts. Therefore, having access to bailouts decreases the *second part* of the endogenous costs of default. This means that from an ex-ante perspective, the bailout economy can sustain less debt since it has a larger default region due to its lower default costs.

Figure 11: Private Consumption

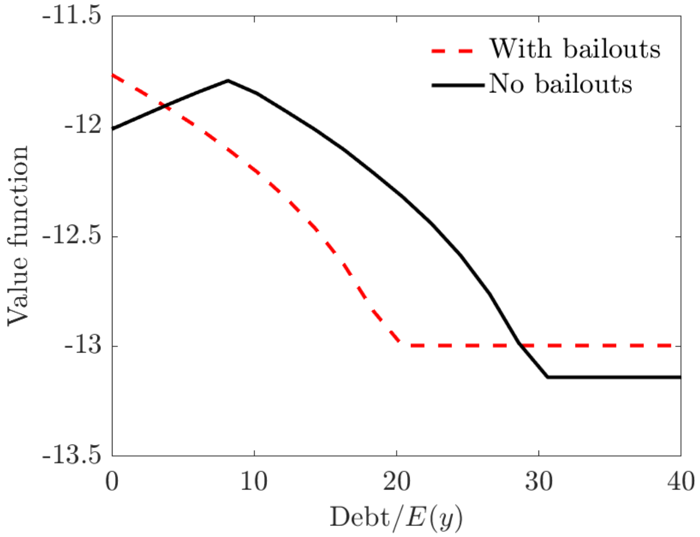


Note: The panels show the equilibrium consumption levels for the cases in which the banking crisis does not occur (left panel) and in which it does (right panel). The plots are constructed assuming average values for TFP and ε.

The flip side of this argument is that the no-bailout economy has higher default costs and can sustain more debt. Having more debt on average, brings about higher liquidity and makes the economy less vulnerable to large realizations of ε, in equilibrium. A higher and cheaper-to-service debt level implies greater consumption, on average, and this holds for almost all debt levels as can be seen in Figure 11. Therefore, even though the no-bailout economy cannot issue asset guarantees, its higher liquidity reduces the need for those guarantees.

The argument developed in the previous paragraphs and the findings shown in Figure 9 imply that living in an economy with unrestricted bailouts is ex-ante preferable only in two extreme cases: either very low or very high initial debt. In the former, having access to bailouts props up liquidity. In the latter case, both economies default and—as discussed above—reentering financial markets is less painful with access to bailouts. For the empirically relevant intermediate cases, restricting the availability to issue bailouts is welfare improving. This is confirmed in Figure 12 where we plot the value functions for both economies.

Figure 12: Value functions with and without bailouts



Note: the graph shows the equilibrium value functions for the economies with (dashed line) and without (solid line) bailouts. The lines are constructed assuming average values for TFP and ε.

The value of fiscal rules and the ex ante undesirability of bailouts. A recent paper by Aguiar and Amador (2019) (see also Hatchondo et al., 2020) shows that the equilibrium in the Eaton and Gersovitz (1981) model with one-period bonds is constrained efficient (once one takes into account market incompleteness and the ability of the government to walk away on its debt obligations). This implies that the ability to commit to a sequence of borrowing policies (i.e. a fiscal rule) does not increase the government's value over the Markov-perfect equilibrium value.

One can think of our restrictions to bailouts, ϕ, as a type of fiscal rule, and therefore the Aguiar and Amador (2019) result would seem to contradict our finding that it is optimal to restrict the issuance of bailouts (that is to say, that we find that some fiscal rules are ex-ante optimal). There is, however, a fundamental reason for which the result in Aguiar and Amador (2019) does not apply in our setup: Government actions affect the production choices of the firms (directly through taxes, indirectly through their effect on the loan rate) and the lending constraint of the banks. These effects, in turn, change the value of repayment and default in ways that are absent in Aguiar and Amador (2019), since they restrict their attention to the canonical Eaton-Gersovitz environment with an endowment economy.[24] The intuition presented above builds on this insight—the economy without bailouts (which can be understood as an economy with a very strict fiscal rule) has an endogenously lower default value which allows it to face better prices (as seen in Figures 10 and 12).[25] In this way, restricting bailout policies (i.e. implementing a particular type of fiscal rule) can improve welfare ex-ante.

Our ex ante result is also related to the work of Chari et al. (2020). They find that financial repression (modeled as forcing banks to hold government debt in their balance sheets) can be optimal in a model that is similar to ours. Ex post financial repression weakens the banks' balance sheets, and raises the cost of default, and this, in turn, reduces the default incentives of the government ex ante, leading to higher welfare.[26]

Take-away. In summary, the results in this section indicate that for the mean debt level in our simulations (15.5 percent of GDP), the economy will be better off if the government cannot issue bailouts. This is a strong result considering that our framework has (i) a benevolent government and (ii) a bailout policy that does not trigger moral hazard concerns. Overall, our results highlight the negative effects of the sovereign-bank nexus (i.e., the 'diabolic loop').

6 Extensions and Sensitivity

In this section, we briefly discuss several extensions to the baseline model to show how our main quantitative results can be generalized.

6.1 Bailouts during exclusion

We have studied the ex ante desirability of bailouts that followed a specific restriction: Bailouts cannot be promised (or disbursed) during exclusion periods. We now relax this restriction and allow the government to issue guarantees even if it is currently excluded from

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[24] For example, Aguiar and Amador (2019) make it clear that their assumption on the value of default being unaffected by the fiscal rule is important in obtaining the result that 'fiscal rules add no value.'

[25] There are, of course, other differences in setup (and assumptions) between our environment and the one in Aguiar and Amador (2019). Apart from the one we highlighted above (of the value of default being affected by the restrictions on the bailouts), the most important one is that the value under repayment is not weakly decreasing in the level of debt: this can be seen clearly in Figure 12 for the no-bailout economy. This is a natural feature of our model: for low enough debt levels, an additional unit of public debt increases liquidity and output, and the benefits from this effect outweigh the costs that the higher debt imposes in terms of distortionary taxation (and higher default probability)—this makes the value of repayment non-monotonic on the debt level (a feature also present in Sosa-Padilla, 2018)

[26] A similar intuition is present in Gennaioli et al. (2014).

borrowing (due to a current or previous default). The recursive formulation of this 'relaxed' problem is a straightforward extension of (20)–(22) and is presented in Appendix C.1.

As argued above, the welfare superiority of the no-bailouts economy comes from the fact that it features larger default costs, and can therefore sustain more debt (which provides liquidity and increases output). Allowing for bailouts during exclusion increases the difference between the default costs in the bailouts and no-bailouts economies. After recalibrating the model to match the same targeted moments as in Section 4.2, the welfare results strengthen: Access to unrestricted bailouts results in a 2.3 percent welfare loss relative to no bailouts (when evaluated at the mean debt level in the simulations).[27]

6.2 Relative weights in the social welfare function

The baseline specification of our model makes the common assumption that the planner only cares about the households' utility. However, we can study the dynamics of the model under different social welfare functions. In particular, one could study the default incentives and the ex ante optimality of bailouts when the planner puts equal weight on the utility of households and banks.

Appendix C.2 presents the results under this alternative assumption. As in the baseline model, Table C.2 (the analogue of Table 4) shows that when we use equal weights in the social welfare function, it remains the case that the no-bailout economy defaults less and faces lower borrowing costs despite accumulating much higher levels of debt compared with the bailout-economy. Importantly, the ex ante sub-optimality of bailouts is robust to this alternative specification: Access to unrestricted bailouts results in a 1.4 percent welfare loss relative to no bailouts (when evaluated at the mean debt level in the simulations).

6.3 Moral hazard

In the baseline model, we abstracted from moral hazard concerns. In an extension of the model, we allow banks to choose the variance of bank capital shocks by paying a convex utility cost that increases with the size of the variance reduction (Appendix C.4). In this extended environment, bailouts give rise to moral hazard considerations as banks may choose a higher variance (i.e. risk) in the anticipation that the government will issue bailouts for large bank capital shocks. As can be expected, we find that the welfare loss from bailouts is

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[27] Table C.1 in the Appendix shows that the contrast between the bailout and the no-bailout economy is now even stronger: the no-bailout economy defaults less, faces lower borrowing costs, despite accumulating much higher levels of debt, compared with the bailout-economy.

considerably larger when bailouts entail moral hazard considerations.

6.4 Bailout announcements affect bank crisis probability

We consider an extension of the model in which the size of the announced bailout policy can reduce the probability of a banking crisis. In Appendix C.4, we show that, in this modified environment, the government optimally chooses to announce disproportionately larger bailouts for more severe banking crises, leading to a different mix of equilibrium banking crises: they are less frequent and less severe relative to the baseline model. We find that allowing for announcement effects slightly reduces the ex ante welfare loss from bailouts, but it remains the case that bailouts are suboptimal from an ex ante perspective.

6.5 State-contingent bailout restrictions

We extend the ex-ante optimal bailout restriction exercise from Section 5 by allowing the restrictions to be state-contingent. That is, we allow the bailout restrictions to be contingent on the level of debt and the realized productivity and banking shocks. We find that the size of allowed bailouts are increasing in productivity and the size of the banking shock, but also find that bailouts may be severely restricted in some states of the world. On average, we find that, consistent with the baseline, bailouts are not significantly restricted for low levels of initial debt, but are strongly restricted for the relevant levels of debt. These results are presented in Appendix C.5.

6.6 Long-term debt

Our baseline model assumed one-period debt. We also consider an extension of the model in which the government issues long-term debt. With this setup, changes in the price of the existing debt owned by banks can also affect the loanable funds, potentially amplifying the doom loop: bank's ability to provide domestic credit is not only affected by actual default but also by increases in default *risk* . We find that extending the maturity of debt leads to higher default frequencies and borrowing costs, but the main result that bailouts are undesirable from an ex ante perspective remains robust. These results are presented in Appendix C.6.

6.7 Bank storage technology

In our baseline model, it is assumed that government debt is the only intertemporal savings instrument available to banks. We relax this assumption by allowing banks to allocate resources not only into government bonds and private loans (intra-period), but also into a storage technology. This technology provides an alternative vehicle for savings, modifying the lending constraint and the bank's dynamic problem. With a reasonable parametrization, we show that the ex-ante suboptimality of unrestricted bailouts remains robust to this extension. These results are presented in Appendix C.7.

6.8 Sensitivity

In this section, we discuss the sensitivity of our main results to changes in parameter values. Overall, we find that our main findings are generally robust to these perturbations around the baseline calibration, but we also discuss which parameters are particularly important for the sub-optimality of bailouts result.

Parameters governing the process for bank capital. We call A bank capital, but a broader interpretation is to think of it as "net assets excluding government debt." In that vein, the calibration of both its baseline level $\overline{A}$ and its shocks ε is crucial for the dynamics of the model.[28] This explains why both $\overline{A}$ and the volatility of bank capital shocks, σ_ε, are part of the SMM procedure described in Section 4.2. In this section, we further explore how the model reacts to small changes in the value of both of these parameters, and corroborate that our main result is robust to this sensitivity analysis.

Table C.7 shows how the moments of interest react to changes in $\overline{A}$, in both directions. Larger values of $\overline{A}$ correspond to higher liquidity in the economy—this lowers the default costs and reduces the debt capacity of the government, other things equal. For both larger and smaller values of $\overline{A}$, it remains true that the model without bailouts sustains higher debt, has a lower volatility of spreads, and a lower default frequency for a given value of $\bar{A}$. Therefore, our headline result regarding the welfare superiority of banning bailouts is qualitatively robust to these alternative values of $\overline{A}$.

Table C.8 illustrates the nonlinear effects of financial shocks on the real economy discussed in Section 4.5—the larger the volatility of the potential loss to banking capital, the greater the need for bailouts. Indeed, Table C.8 shows that a higher value of σ_ε is associated with a higher default frequency, and higher and more volatile spreads. Even though the welfare

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[28] See discussion in footnote 8.

loss from access to bailouts decreases slightly in this case, we still find that banning bailouts altogether is optimal from an ex ante point of view.

Importantly, it may be the case that the ex ante suboptimality bailout result would not materialize for even higher values of $\overline{A}$ or σ_ε than considered here. However, such higher values would imply larger output volatility and larger bailouts than in the data (as these are the data moments that we targeted to discipline these values), and thus we rule out these alternative calibrations.

Parameters governing the probability of default. Many parameters in the model affect the probability of default, but the two most direct determinants are the household discount factor β and the reentry probability θ.

The reentry probability affects the welfare loss from bailouts in two opposing directions. On the one hand, with a higher θ, the default costs faced by the government with access to bailouts are smaller, leading to lower debt capacity and welfare (as explained in Section 5). Therefore, for a given level of debt, a higher θ is associated with a larger welfare loss from bailouts. On the other hand, a higher θ lowers the equilibrium debt level in the economy with bailouts and since welfare losses from bailouts increase with debt (see Figure 9), this leads to lower welfare losses. We show in Appendix C.8 that the latter effect dominates, leading to higher values of θ being associated with smaller welfare losses from bailouts.

When the household is more patient (i.e. has a higher discount factor β), the probability of default decreases, with and without bailouts. By reducing the sovereign-bank diabolic loop, a higher discount factor reduces the welfare loss from bailouts, though it remains the case that bailouts are suboptimal from an ex ante perspective.

It is possible that even higher values of θ or β could reverse the suboptimality of bailouts result. We rule out these alternative calibrations since even higher values of θ would imply even lower levels of government debt and higher values of β would imply default frequencies that are too low for the set of economies we consider—the higher value of β considered in Appendix C.8 features default frequencies of 0.3 and 0.2 percent, with and without bailouts, implying 2–3 defaults every 1,000 years.

Frisch elasticity. Our baseline calibration sets the wage elasticity of labor supply, $1/(\omega - 1)$, to an intermediate value from within the range of estimates in the literature. We have argued that the diabolic loop that bailouts create is costly because bailouts are (partly) financed with distortionary labor taxes. Therefore, one might expect that for a lower elasticity, this distortion will be smaller and it could moderate or overturn the baseline welfare results. While it is the case that, holding debt levels fixed, lower elasticity leads to a smaller welfare loss, we show in Appendix C.8 that access to bailouts still results in a welfare loss.

Other parameters. Appendix C.8 also presents a thorough sensitivity analysis to other parameters of interest. In a nutshell, perturbations around the benchmark values do not affect our main conclusions, especially the result regarding the ex ante welfare inferiority of having access to bailouts. A detailed explanation of these exercises can be found in Appendix C.8.

7 Conclusion

We study the dynamic interplay between sovereign default, banking crises, and government bailouts. Empirically, we document that when governments intervene to support distressed banking sectors, contingent guarantees are the most prevalent instrument.

We then develop a general-equilibrium sovereign default model in which a benevolent government chooses debt, default, distortionary taxes, and bank bailouts to maximize household welfare. The economy faces aggregate shocks to firm productivity and to bank capital. Anticipating adverse banking shocks, banks curtail lending. The sovereign can announce guarantees: state-contingent transfers that compensate banks for capital losses in crisis states—a bailout. Defaults are costly because they deteriorate bank balance sheets and temporarily cut off the sovereign from credit markets, eliminating bailout capability; credit, output, and consumption fall. The benefit of default is the elimination of outstanding debt, which relaxes the fiscal budget and lowers distortionary taxation. The framework admits a two-way amplification between sovereign risk and bank risk—a "doom loop."

Quantitatively, a banking crisis raises the default probability and increases both the level and volatility of sovereign spreads. Equilibrium guarantees exhibit clear comparative statics: ceteris paribus, they are (i) decreasing in public debt (less fiscal space), (ii) increasing in productivity (credit is more valuable and borrowing cheaper), and (iii) increasing in the severity of banking crises (nonlinear effects of financial shocks).

Although bailouts mitigate crisis-time damage, ex ante the economy is better off without them: access to bailouts lowers default costs, which raises default frequency and depresses debt capacity, output, and consumption. This conclusion is robust across alternative specifications—including the ability to extend bailouts during default/exclusion periods, the presence of long-term sovereign debt, the ability of banks to save in default-free assets —as well as other modeling variations.

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A Contingent Liabilities

In this section, we consider a broader notion of contingent government interventions by looking at the changes in government *contingent liabilities* instead of *government guarantees*. In addition to government asset guarantees, the concept 'contingent liabilities' includes public–private partnerships (PPP) recorded off-balance sheet of the government and liabilities of government controlled entities classified outside of general government operations. For most countries, *government guarantees* make up the largest share in *government contingent liabilities*. Because contingent liabilities are also stocks, we calculate the annual change in contingent liabilities as a share of GDP, and take the average of that ratio across all countries.

Figure A.1: Government contingent liabilities and capital transfers

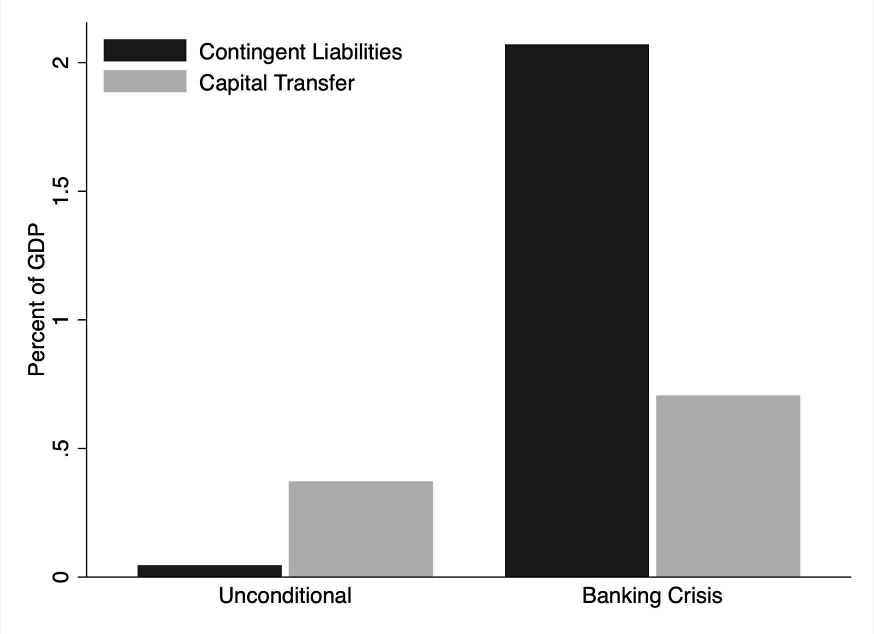


Figure A.1 shows a side-by-side comparison of contingent liabilities and capital transfers in the entire sample and conditional on banking crisis. We obtain a similar pattern as before: Contingent liabilities exceed 2 percent during banking crises and they are close to zero unconditionally.

B Data Appendix

Data description for Figures 1 and A.1

We obtain the data for government guarantees, contingent liabilities, and capital transfers from Eurostat. We obtain these series for 23 countries, which are Austria, Belgium, Bulgaria, Croatia, Cyprus, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Portugal, Slovenia, Spain, Sweden, the Czech Republic, the Netherlands, and the United Kingdom. Our sample is limited by the data availability, and it covers the years 2007–2019. For each country, we calculate the first difference of government guarantees and contingent liabilities, and we divide them by the GDP series obtained from the World Bank Database to generate the plots. Next, we calculate the share of capital transfers in GDP for each country between 2007–2019. Using the banking crisis dates from Laeven and Valencia (2020) we create the sample conditional on banking crises.

Data description for calibration and external validity

We calculate the unconditional default frequency and default frequency conditional on banking crises using the crises dates given in Laeven and Valencia (2020). This dataset covers the years 1970–2017. The sample contains 21 advanced and 17 emerging market economies as in Davis et al. (2016). The unconditional default frequency is calculated as the total count of default events divided by the total number of country-year pairs.

The share of government spending in GDP is calculated using the data from OECD. Our sample consists of GIIPS during 1999–2019. First, for each country we calculate the average public consumption as a share of GDP and then compute the median across country averages.

We calculate the domestic debt to GDP data from the ECB and OECD datasets. We choose the period between 1999 and 2019. Our sample covers the same 23 countries above plus Estonia, Malta, Poland, Romania, and Slovakia. For the majority of the countries in our sample, domestic gross government debt series as a share of GDP are readily available. For these countries, we calculate the average debt-to-GDP over 1999–2019. For Ireland and the United Kingdom, ECB only provides total debt values. Therefore, first, we calculate the average share of domestic debt in total debt from the OECD, which is the average share of marketable debt held by domestic residents in the total marketable debt. Because of data limitations for Ireland and the UK, we can construct the annual shares between 1999–2006 and between 1999–2010, respectively. We use these shares to calculate the domestic debt levels for Ireland and the UK, and divide them by the corresponding GDP series. Finally, the median domestic debt to GDP ratio for the whole sample between 1999–2019 is given by 25.8 percent.

We calculate the output volatility for GIIPS using the GDP per capita series obtained from OECD data between 1970–2019. First, for each country, we compute the standard deviation of HP-filtered log output. Then we compute the median across countries to obtain 3.4 percent. For moments related to the spread, we obtain interest rates for GIIPS from the OECD for 1999–2019. We calculate the spread as the difference between nominal yield on 10-year government bonds of each country and that of Germany. For each country, we compute the average and standard deviation of the spread and the correlation of spread and the HP-filtered GDP. Finally, we compute the medians of average spread, standard deviation of spread, and the correlation of spread with the GDP to obtain our moments.

The correlation between transfers and debt reported in Table 2 is estimated using HP-filtered government guarantees and HP-filtered short-term securities. Short-term securities are defined as government consolidated gross debt at face value and obtained from Eurostat.

Data description for dynamics around banking crises

To compute the sovereign yields, we use Jordà et al. (2017) Macrohistory database, which covers 1950–2016 and 17 advanced economies including Italy, Portugal and Spain. The sovereign yield is calculated as the nominal interest rate minus the inflation rate. Each country's output series is detrended using its own average growth rate. We define 7-year windows centered around banking crises. We compute unconditional averages across windows, as well as averages conditional on debt being above the country's 75th percentile of debt at the start of the banking crisis.

C Appendix to Section 6

C.1 Bailouts during exclusion

In the baseline model, we assume that the government is unable to issue bailouts during periods of default and exclusion. Here, we explore the implications of relaxing this assumption. Given government policies, the value of the representative bank when the government does not have access to credit is then given by:

$$W^D(s) = \max_{\ell^s} \mathbb{E}_A \left\{ \begin{array}{ll} \max\limits_{x} & x + \delta \mathbb{E}_{s'|s}\left[\theta W^R(0;0,s') + (1-\theta) W^D(s')\right] \\ \text{s.t.} & x \leq T_{\text{def}}(s,A) + r_{\text{def}}(s,A)\ell^s \end{array} \right\} \tag{28}$$

$$\text{s.t. } \ell^s \leq \min_A \{A + T_{\text{def}}(s,A)\}. \tag{29}$$

The value of default for the government is given by:

$$V^D(s) = \max_{\tau,T} \mathbb{E}_A \Big\{ U\big(c\,(s,A)\,, n\,(s,A)\,\big) + \beta\, \mathbb{E}_{s'|s}\left[\theta V\,(0,s') + (1-\theta) V^D\,(s')\right] \Big\} \tag{30}$$

subject to:

$$\begin{aligned} &\tau\, w_{\text{def}}(s,A)\, n_{\text{def}}(s,A) = g + T && \text{(gov't b.c.)} \\ &c_{\text{def}}(s,A) + x_{\text{def}}(s,A) + g = zF\left(n_{\text{def}}(s,A)\right) && \text{(resource constraint)} \end{aligned}$$

$$\left. \begin{array}{ll} T = 0 & \text{if } A = \overline{A} \\ 0 \leq T \leq \varepsilon \overline{A} & \text{if } A = \overline{A}(1-\varepsilon) \end{array} \right\} \quad \text{(constraint on } T\text{)}$$

and

$$\left. \begin{array}{l} r_{\text{def}}(s,A) = \max\left\{ \frac{z n_{\text{def}}(s,A) F_n}{\underline{A}(\varepsilon) + T(\underline{A}(\varepsilon))} - \frac{1}{\gamma}, 0 \right\} \\ -\frac{U_n}{U_c} = (1-\tau)\, w_{\text{def}}(s,A) \\ zF_n = (1 + \gamma\, r_{\text{def}}(s,A))\, w_{\text{def}}(s,A) \\ \ell_{\text{def}}(s,A) = \gamma w_{\text{def}}(s,A) n_{\text{def}}(s,A) \\ x_{\text{def}}(s,A) = T + r_{\text{def}}(s,A) \ell_{\text{def}}(s,A) \end{array} \right\} \quad \text{(comp. eq. conditions)}$$

where $c_{\text{def}}(s;\tau)$, $n_{\text{def}}(s;\tau)$, $x_{\text{def}}(s;\tau)$, $\ell_{\text{def}}(s;\tau)$, $w_{\text{def}}(s;\tau)$, and $r_{\text{def}}(s;\tau)$ represent the equilibrium quantities and prices for the private sector given public policy (under default) and the dependence on government policies (τ, T) has been omitted. The other equations that govern the model remain the same as in the baseline.

In this robustness exercise, we recalibrate the model with the same strategy as described in Section 4.2. The parameters affected by this recalibration are given by $\beta = 0.90$, $\bar{A} =$

0.21, $\sigma_e = 4.94$ (All other parameters remain the same as in the baseline). Notice that in Table C.1 (the analogue of Table 4), the simulated moments from the extended model that allows for bailouts in default are very similar to the baseline model. This is directly a result of re-calibrating the model to feature the same frequency of defaults as in the baseline model. Table C.1 also shows that the contrast between the bailout and the no-bailout economy is now even stronger. The no-bailout economy defaults less, faces lower borrowing costs, despite accumulating much higher levels of debt, compared with the bailout-economy. As a result, the welfare cost of bailouts is even larger than in the baseline model.

Table C.1: Simulated moments

	Bailouts during default	No bailouts
Default frequency	0.5*	0.1
Sovereign spread		
mean	0.7	0.3
standard deviation	0.8	0.2
corr(GDP, spread)	–0.7	–0.6
Debt/GDP	18.1	57.0
Mean lending rate	0.2	0.1
Welfare gain of bailouts	–2.3	

Units: percent (except for corr. coeff.). * denotes targeted moments.

C.2 Relative weights in the social welfare function

In the baseline model, we assume that the government puts full weight on the welfare of households. Here, we explore the implications of assuming, alternatively, that the government puts equal weight on the welfare of the households and banks.

Formally, the planner's value of repaying can be re-written as:

$$V^R(B, s) = \max_{\Phi} \mathbb{E}_A \Big\{ \mu U\big(c\,(\kappa;\Phi)\,, n\,(\kappa;\Phi)\,\big) + (1-\mu) x\,(\kappa;\Phi) + \beta\, \mathbb{E}_{s'|s} V\,(B', s')\,\Big\} \tag{31}$$

subject to the resource constraint, government budget constraint, restriction on T, and competitive equilibrium conditions found in problem (21).

Similarly, the planner's value of defaulting can be formulated as:

$$V^D(s) = \max_{\tau} \left\{ \begin{array}{l} \mu U\big(c_{\text{def}}\,(s;\tau)\,, n_{\text{def}}\,(s;\tau)\,\big) + (1-\mu) x_{\text{def}}(s;\tau) \\ +\beta\, \mathbb{E}_{s'|s}\big[\theta V\,(0, s') + (1-\theta) V^D\,(s')\,\big] \end{array} \right\} \tag{32}$$

subject to the resource constraint, government budget constraint, and competitive equilibrium conditions found in problem (22).

In this robustness exercise, we recalibrate the model with $\mu = 0.5$ and the same strategy as described in Section 4.2. The parameters affected by this recalibration are given by $\beta = 0.82$, $\bar{A} = 0.31$, $\sigma_e = 3.75$ (All other parameters remain the same as in the baseline). As in the baseline, Table C.2 (the analogue of Table 4) shows that the no-bailout economy defaults less, faces lower borrowing costs, despite accumulating higher levels of debt, compared with the bailout-economy. Importantly, sub-optimality of bailouts is robust to this alternative specification.

Table C.2: Simulated moments ($\mu = 0.5$)

	With bailouts	No bailouts
Default frequency	0.5*	0.4
Sovereign spread		
mean	0.7	0.6
standard deviation	0.7	0.6
corr(GDP, spread)	–0.3	–0.3
Debt/GDP	15.5	25.7
Mean lending rate	0.0	0.2
Welfare gain of bailouts	–1.1	

Units: percent (except for corr. coeff.). * denotes targeted moments.

C.3 Moral hazard

In this section, we consider an extension of the model so that bailouts can trigger moral hazard considerations. Assume that banks can decide the variance of capital loss shocks ε (i.e., σ_ε^2) one period in advance, as a stand-in for risk-taking behavior by banks. Let the utility cost—suffered by banks—of choosing $\hat{\sigma}_\varepsilon$ be given by

$$X(\hat{\varepsilon}) = \Psi(\hat{\sigma}_\varepsilon - \overline{\sigma}_\varepsilon)^2 \tag{33}$$

where $\overline{\sigma}_\varepsilon^2$ is the baseline level of volatility and $\Psi > 0$. When $\Psi \to \infty$, reducing the variance is prohibitively costly and is equivalent to the baseline model (with no moral hazard considerations). Conversely, when $\Psi \to 0$, reducing the variance is costless, leading banks to choose zero risk—with or without bailouts—effectively eliminating banking crises and bailouts altogether. For intermediate values of $\Psi > 0$, banks may choose a higher variance (i.e., risk) in anticipation of bailouts, thus triggering moral hazard considerations. We report the results for $\Psi = 0.05$ in Table C.3. As in the baseline model, the economy without bailouts defaults less frequently and faces lower borrowing costs, despite accumulating higher levels of debt, relative to the economy with bailouts. We can also see that banks choose a larger variance with bailouts, relative to the banks without bailouts. Finally, the welfare loss from bailouts is even larger—a loss of 5.2 percent—compared with the baseline welfare loss of 1.5 percent.

Table C.3: Simulated moments ($\Psi = 0.05$)

	With bailouts	No bailouts
Default frequency	0.4	0.2
Sovereign spread		
mean	0.6	0.4
standard deviation	0.6	0.3
corr(GDP, spread)	–0.2	–0.5
Debt/GDP	19.8	61.9
Mean lending rate	0.0	0.3
Relative volatility $\widehat{\sigma}_\varepsilon/\overline{\sigma}_\varepsilon$	1.0	0.8
Welfare gain of bailouts	–5.2	

Units: percent (except for correlation coeff. and relative volatility).

C.4 Bailout announcements affect banking crisis probability

We consider the possibility that the proportional size of the announced bailout policy can reduce the probability of a banking crisis. In particular, assume that $\pi(\cdot)$ takes the form:

$$\pi\left(T/\varepsilon\overline{A}\right) = \bar{\pi} \times \left(1 - \eta T/\varepsilon\overline{A}\right) \tag{34}$$

where $\eta \in [0, 1]$ governs the strength of the announcement effect. If $\eta = 0$, the announcement has no effect on the probability of a banking crisis, as in the baseline economy. As η increases, the probability of a banking crisis declines with relatively larger bailouts.

The rest of the model remains identical to the baseline model. As can be seen in Table C.4, stronger announcement effects increase the size of the promised bailouts (first row), reducing the probability of banking crises to 1.6 percent when $\eta = 0.9$, compared with 1.8 percent when $\eta = 0.0$ (second row). Because the government announces disproportionately larger bailouts for more severe banking crises, the banking crises that do occur tend to be milder. As a result, conditional on banking crises, actual bailout payments are smaller (third row). Allowing for bailouts to have announcement effects slightly reduces the ex ante welfare loss from bailouts (fourth row). Nevertheless, the ex ante suboptimality of bailout result is robust to including announcement effects.

Table C.4: Simulated moments

	Announcement effect (η)		
	0.0	0.5	0.9
Bailout/GDP (promised)	0.9	0.9	1.2
Banking crisis prob.	1.8	1.7	1.6
Bailout/GDP (conditional on BC)	1.7	1.5	1.2
Welfare gain of bailouts	−1.48	−1.47	−1.46

Units: percent.

C.5 State-contingent bailout restrictions

In this section, we extend the ex-ante optimal bailout restriction exercise from Section 5 by allowing the restrictions to be state-contingent. That is, we modify the constraint on $T(B, s, A)$ as follows:

$$\left.\begin{array}{cl} T = 0 & \text{if } A = \overline{A} \\ 0 \leq T \leq \min\{\varepsilon \overline{A}, \max\{0, \phi(B, s)\}\} & \text{if } A = (1-\varepsilon)\,\overline{A} \end{array}\right\} \text{(constraint on } T\text{)}$$

where $\phi(B, s) = \phi_0 + \phi_B B + \phi_\varepsilon \varepsilon + \phi_z \log(z)$.

With this modified framework, we compute the ex ante welfare-maximizing coefficients $\varphi \equiv \{\phi_0, \phi_B, \phi_\varepsilon, \phi_z\}$ for different levels of initial debt, B_0. First, we solve for $\Lambda(B_0; \varphi)$, the permanent increase in consumption needed in the no-bailout economy to make households indifferent between this economy and another with φ. Formally, $\Lambda(B_0; \varphi)$ is implicitly defined by

$$\mathbb{E}_s V_\Lambda(B_0, s; 0) = \mathbb{E}_s V(B_0, s; \varphi) \tag{35}$$

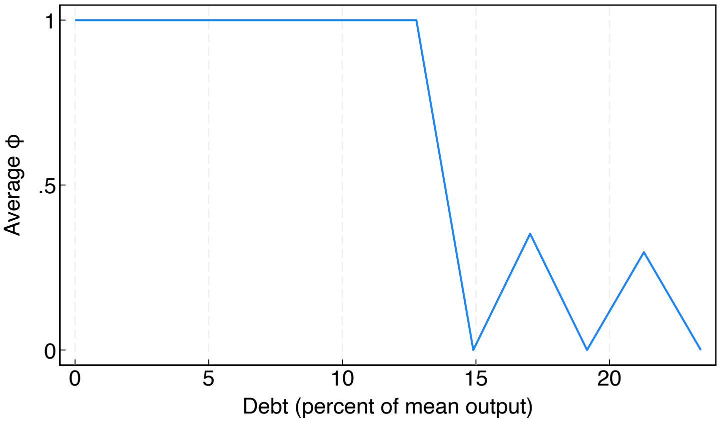
where the expectation is taken over the ergodic distribution of $s = \{z, \varepsilon\}$ and $V_\Lambda(B_0, s; 0)$ is the value resulting from a permanent increase in consumption Λ in the economy without bailouts. Second, for each initial debt level B_0, we compute the welfare maximizing set of coefficients, φ.

We find that optimal restrictions generally involve $\phi_0 < 0,\ \phi_B > 0,\ \phi_\varepsilon > 0,\ \phi_z > 0$. That is, the state-contingent cap on bailouts is increasing in both productivity and the severity of the banking shock. The state-contingent limit on bailouts is also increasing in the level of debt ($\phi_B > 0$), though this coefficient decreases with initial debt B_0. Note that these coefficients allow for bailouts to be banned in some states of the world, i.e. $\phi(B, s) \leq 0$.

We analyze the optimal restrictiveness implied by φ in two ways. First, we examine, for each level of initial debt B_0, an average measure of allowable bailouts, evaluated at the mean of debt, productivity, and banking shock levels, expressed as a fraction of the average banking shock (See Figure C.2). Consistent with our baseline results, for very low levels of initial debt, it is optimal to not restrict bailouts significantly. For high debt levels (exceeding 13 percent of mean output), it is optimal to put more significant restrictions on bailouts. At simulated mean debt levels (15.5 percent of GDP), state-contingent restrictions on bailouts call for substantial restrictions, and are ruled out on average. At simulated mean debt levels (15.5 percent of GDP), state-contingent restrictions on bailouts call for substantial restrictions, and are ruled out on average.

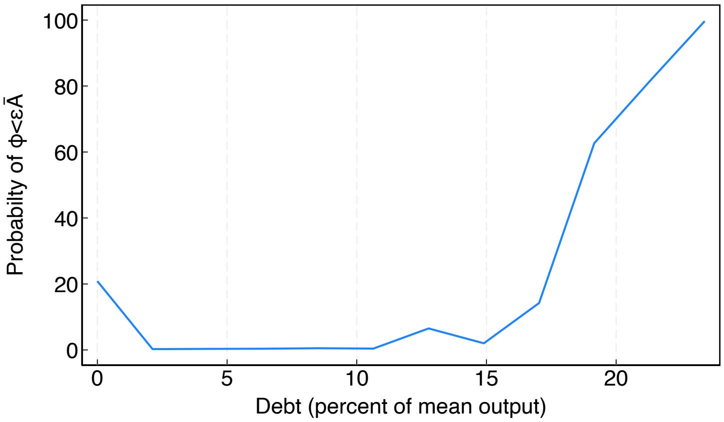
Second, we plot the ex ante probability that bailouts are restricted to be below the potential banking sector loss, for any given state, that is, $\Pr_{B_0}[\phi(B, s) \leq \varepsilon \overline{A} | \varepsilon > 0]$. Figure

Figure C.2: Optimal bailout restrictions (average)



Note: This figure shows, for each level of initial debt B_0, the allowable bailouts evaluated at the mean productivity and banking shock levels, as a share of the average banking shock size. That is, for each initial debt B_0, we plot $\max\left\{0, \min\left\{1, \dfrac{\phi_0 + \phi_B \mathbf{E}[B] + \phi_\varepsilon \mathbf{E}[\varepsilon] + \phi_z \mathbf{E}[z]}{\mathbf{E}[\varepsilon]\bar{A}}\right\}\right\}$.

Figure C.3: Optimal bailout restrictions



Note: This figure shows, for each level of initial debt B_0, the probability that the maximum allowable debt, given by $\phi(B, s)$, is strictly less than the size of the banking shock, $\varepsilon\bar{A}$, conditional on $\varepsilon > 0$.

C.3 plots this probability for different levels of initial debt, B_0. For very low levels of initial debt, it is optimal to not restrict the size of bailouts in most states of the world, that is this probability is close to zero. For higher debt levels—above 15 percent of GDP—it is optimal to put more significant restrictions on bailouts, with bailouts restricted in 20–100 percent of states. Thus, at simulated mean debt levels (15.5 percent of GDP) or higher, state-contingent restrictions on bailouts call for substantial restrictions, while not banning them outright as was the case with constant restrictions in the baseline.

C.6 Long-term debt

In this section, we consider the robustness of our main results to incorporating long-term debt. Every period, a fraction ν matures and pays 1 unit of consumption, and the remaining fraction, $1-\nu$, pays a coupon λ and has a continuation price $q(B', s)$. Thus, total per-period payments are equal to $\nu + (1-\nu)\lambda$. With long-term debt, changes in the price of the existing debt owned by the banks also affect the loanable funds. That is, the banks' loanable funds are now given by:

$$\ell^s \leq \min_A \{ b\left[\nu + (1-\nu)(\lambda + q(B', s))\right] + A + T(B, s, A)\} \,. \tag{36}$$

As before, let $\kappa \equiv (B, s, A)$ denote the complete aggregate state and $\Phi \equiv \{\tau, T, B'\}$ summarize the fiscal policies under repayment. The value of repaying can then be written as:

$$V^R(B, s) = \max_{\Phi} \mathbb{E}_A \Big\{ U\big(c\,(\kappa; \Phi)\,, n\,(\kappa; \Phi)\big) + \beta\, \mathbb{E}_{s'|s} V\,(B', s')\,\Big\} \tag{37}$$

subject to:

$$\tau\, w(\kappa; \Phi)\, n(\kappa; \Phi) + [B' - (1-\nu)B]q(B', s) - B[\nu + (1-\nu)\lambda] \;= g + T \qquad \text{(gov't b.c.)}$$

$$c(\kappa; \Phi) + x(\kappa; \Phi) + g = zF\,(n(\kappa; \Phi)) \qquad \text{(resource constraint)}$$

$$\left.\begin{array}{ll} T = 0 & \text{if } A = \overline{A} \\ 0 \leq T \leq \varepsilon \overline{A} & \text{if } A = \overline{A}(1-\varepsilon) \end{array}\right\} \qquad \text{(constraint on } T\text{)}$$

and the competitive equilibrium conditions

$$\begin{aligned}
& q(B', s) = \delta \mathbb{E}_{s'|s} \Big\{ \left[1 - d(B', s')\right] \mathbb{E}_{A'}\big[(1 + r(\kappa'; \Phi'))(\nu + (1-\nu)(\lambda + q(B'', s')))\big] \Big\} \\
& r(\kappa; \Phi) = \max \Big\{ \frac{zn(\kappa;\, \Phi)F_n}{B[\nu + (1-\nu)(\lambda + q(B', s))] + \underline{A}(\varepsilon) + T\,(\underline{A}(\varepsilon))} - \frac{1}{\gamma}, 0 \Big\} \\
& -\frac{U_n}{U_c} = (1-\tau)\, w\,(\kappa; \Phi) \\
& zF_n = (1 + \gamma\, r\,(\kappa; \Phi))\, w\,(\kappa; \Phi) \\
& \ell\,(\kappa; \Phi) = \gamma w(\kappa; \Phi) n(\kappa; \Phi) \\
& x(\kappa; \Phi) = T + B[\nu + (1-\nu)\lambda] - q(B', s)[B' - (1-\nu)B] + r(\kappa; \Phi)\ell\,(\kappa; \Phi)
\end{aligned}$$

where $c(\kappa; \Phi)$, $n(\kappa; \Phi)$, $x(\kappa; \Phi)$, $\ell(\kappa; \Phi)$, $w(\kappa; \Phi)$, $r(\kappa; \Phi)$, and $q(B', s)$ represent the equilibrium quantities and prices for the private sector given public policy (under repayment). The value of default is unchanged from the baseline model.

Table C.5 reports the simulated moments for various debt maturities. $\nu = 1$ corresponds to our baseline model with one-period debt. Columns 2–4 correspond to versions of the model with maturities of 1.5, 2, and 4 years, respectively, where all parameters of the model are held identical, except for the debt maturity parameter, ν. With longer debt maturities, borrowing costs for the government increase, reflecting higher default probabilities. Other moments remain similar to the baseline, and in particular, the ex ante suboptimality of bailouts remains robust to longer debt maturities.

Table C.5: Simulated moments

	Debt maturity parameter (ν)			
	1.0 (baseline)	0.75	0.5	0.25
Default frequency	0.5	0.7	1.1	2.6
Sovereign spread				
mean	0.7	0.7	1.2	2.9
standard deviation	0.6	0.5	0.7	1.4
corr(GDP, spread)	–0.3	–0.5	–0.5	–0.5
Debt/GDP	15.6	16.5	16.7	17.4
Mean lending rate	0.0	0.0	0.0	0.1
Welfare gain of bailouts	–1.5	–1.6	–1.6	–1.6

Units: percent (except for corr. coeff.).

C.7 Bank's storage technology

In this extension, we allow banks to allocate resources not only into government bonds and private loans, but also into a storage technology. This technology provides an alternative (potentially state-dependent) vehicle for savings, modifying the lending constraint and the bank's dynamic problem. In what follows, we denote with k the bank's individual storage position and with K the aggregate storage level.

Loanable funds. Banks' loanable funds now consist of four components: (i) sovereign bonds, b; (ii) bank capital, A, which is subject to shocks as in the baseline; (iii) the return on the storage technology, $M(k, \varepsilon)$, where k is the previous period's storage decision and where we make explicit that this return is affected by the banking shocks; and (iv) government guarantees, $T(B, K, s, A)$.

The return on the storage technology is assumed to be as follows:

$$M(k, \varepsilon) = \begin{cases} \tilde{M}(k) & \text{if } A = \overline{A} \\ (1-\varepsilon)\,\tilde{M}(k) & \text{if } A = \underline{A}(\varepsilon) \end{cases}, \tag{38}$$

where $\tilde{M}(k)$ is a function capturing the storage return absent banking shocks. This formulation implies that the storage return is affected by the same banking shock (potentially) hitting $\overline{A}$.

The lending constraint (under repay), is therefore given by[29]

$$\ell^s \;\leq\; (1-\varepsilon)\left(A + \tilde{M}(k)\right) + b + T(B, K, s, A)\,, \tag{39}$$

where we already imposed the worst-case realization of the bank capital and storage return.

Bank's value functions. With government access to credit markets, the bank's budget constraint is given by

$$x \leq T(B, K, s, A) + b + M(k, \epsilon) - q(B', K', s)b' - k' + r(B, K, s, A)\ell^s \tag{40}$$

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[29] In the case of default, the last two terms of the right-hand side drop out: debt (b) is not being repaid and (following the baseline specification of our model) we do not allow for bailouts (T) during defaults.

In this case, the bank's value function is given by:

$$W^R(b,k;B,K,s) = \max_{\ell^s} \; \mathbb{E}_A \left\{ \begin{array}{ll} \max\limits_{x,b',k'} & x + \delta \mathbb{E}_{s'|s}\big[(1-d')W^R(b',k';B',K',s') + d'W^D(k';K',s')\big] \\ \text{s.t.} & (40) \end{array} \right\}$$
$$\text{s.t.} \;\; (39),$$

where the bank takes as given the evolution of aggregate capital.

During default, the bank's value is:

$$W^D(k;K,s) = \max_{\ell^s,x,k'} \; x + \delta \mathbb{E}_{s'|s}\Big[\theta W^R(0,k';0,K',s') + (1-\theta)W^D(k';K',s')\Big] \tag{41}$$

$$\text{s.t. } x \leq M(k,\varepsilon) - k' + r_{\text{def}}(K,s)\ell^s, \tag{42}$$

$$\ell^s \leq \; (1-\varepsilon)\Big(A + \tilde{M}(k)\Big) . \tag{43}$$

The option to store some resources without the risk of default (but still subject to banking shocks) gives an additional Euler equation to the bank's problem. For the case of repayment, this is:[30]

$$1 = \delta\, \mathbb{E}_{s'|s}\Big\{ M'(k',\varepsilon')\big[(1-d')\mathbb{E}_{A'}(1 + r(B',K',s',A')) + d'\, \mathbb{E}_{A'}(1 + r_{\text{def}}(K',s'))\big]\Big\} . \tag{44}$$

This condition, as usual, equates the marginal cost of saving one unit in the storage option to the discounted expected marginal benefit of doing so. Equation (44) complements the bond-pricing and loan-market equilibrium conditions from the baseline model.

Households and firms. The problems of the other private agents remain conceptually unchanged from the baseline model.

Determination of government policies. It is straightforward to adjust the equations in Section 3.2 for the case in which the banks can also save in a default-free storage alternative. The main differences are: (i) there is an additional aggregate state variable, K, and (ii) the competitive equilibrium conditions (under both repayment and default) include an additional equation, the storage Euler equation from the bank's problem. For brevity, we omit the full mathematical exposition of this problem.

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[30] A similar Euler equation holds for the case of default.

Calibration. Following Sosa-Padilla (2018), we assume that the storage return (absent banking shocks) is:

$$\tilde{M}(k) = \Gamma_k k^{\alpha_k}$$

where Γ_k is a scaling parameter controlling the average return and α_k controls the curvature of the return function.

We adopt a partial recalibration strategy. First, we set $\alpha_k = 0.97$ (as in Sosa-Padilla, 2018). Accumulating k in this model is similar to hoarding cash (in a similar but nominal model). Hence, conditional on $\Gamma_K \leq 1$, having $\alpha_k < 1$ implies a negative net real rate of return on the storage (a common occurrence for cash equivalent instruments in economies with at least moderate inflation). Second, we calibrate $\{\overline{A}, \Gamma_k\}$ to match the mean bailouts to GDP (1.7%) and the mean K-to-assets ratio (3.9%), keeping every other parameter unchanged.[31,32] Under this calibration, the average net return on storage is approximately -24%, implying a very high real cost of holding cash-equivalent instruments. We explore the sensitivity of our results to higher values of Γ_k below.

Main Result. Table C.6 shows the main simulation results. For this partial recalibration, our main policy result, the ex ante undesirability of bailouts, is robust to this extension.

Table C.6: Simulated moments for the storage-economy

	With bailouts	No bailouts
Default frequency	0.6	0.3
Sovereign spread		
mean	0.6	0.3
standard deviation	0.8	0.6
corr(GDP, spread)	–0.3	–0.3
Debt/GDP	14.9	25.1
Bailout/GDP	1.9 *	0
K/Assets	3.1*	1.8
Mean lending rate	0.0	0.2
Welfare gain of bailouts	–1.4	

Units: percent (except for corr. coeff.). * denotes targeted moments.

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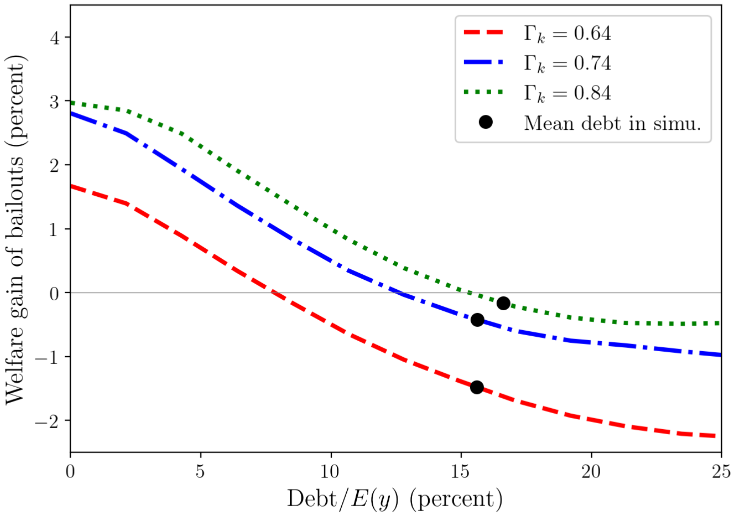
[31] The data counterpart for the bailouts-to-GDP ratio is the same as in the baseline model. For the K-to-assets ratio we use the ECB's Consolidated Banking data (CBD2) and focus on the series named "Cash and cash balances with central banks (% of total assets)." The average reported corresponds to the period 2007–2019, for the GIIPS countries.

[32] The resulting parameter values are $\overline{A} = 0.278$ and $\Gamma_k = 0.64$.

Sensitivity to Γ_k. Given that the baseline $\Gamma_k = 0.64$ implies a low return on storage, we explore the robustness of our welfare result to higher values of Γ_k. For each value of Γ_k, we recalibrate $\overline{A}$ to match the bailout-to-GDP target of 1.7%. Figure C.4 plots the welfare gain of unrestricted bailouts as a function of initial debt for $\Gamma_k \in \{0.64, 0.74, 0.84\}$. Note that $\Gamma_k = 0.84$ implies an average return on storage of approximately -0.5%, i.e. essentially zero. As the storage technology improves, the welfare cost of bailouts attenuates: at the simulated mean debt level, the welfare loss shrinks from -1.4% ($\Gamma_k = 0.64$) to -0.3% ($\Gamma_k = 0.74$), and further to -0.2% ($\Gamma_k = 0.84$). Overall, the main takeaways are robust to these values of Γ_k: (i) the welfare gain of bailouts is decreasing in the initial debt level, and (ii) bailouts remain ex ante undesirable at the equilibrium debt level.

Figure C.4: Welfare gains for different Γ_k values



C.8 Sensitivity

We study the baseline model's sensitivity to eight parameters, i.e. the bank's baseline capital ($\bar{A}$), the financial shock shape (σ_ε), the Frisch elasticity ($1/(\omega-1)$), the household discount factor (β), the strength of the working capital constraint (γ), the probability of bank capital shock (π), the labor share (α), and the probability of financial redemption (θ). We change one parameter value at a time, keeping all others at their baseline values. We confirm that our main results are robust to these alternative parameter values.

1. **Bank's baseline capital,** $\bar{A}$. During defaults, the government is unable to bailout the banks and increase their liquidity. As a result, higher values of $\bar{A}$ reduce the costs of default (since it implies higher loanable funds) and reduces the debt capacity of the government. Nevertheless, the model without bailouts still sustains higher debt, has a lower volatility of spreads, and a lower default frequency, for a given value of $\bar{A}$. We also find confirmation for our headline result regarding the welfare superiority of banning bailouts.

Table C.7: Sensitivity to $\bar{A}$

	Baseline model	Model without bailouts
Low $\bar{A}$ ($\bar{A} = 0.26$)		
Default frequency	0.6	0.4
Sovereign spread		
mean	0.8	0.5
standard deviation	0.7	0.5
corr(GDP, spread)	–0.5	–0.4
Debt/GDP	22.9	33.4
Mean lending rate	0.1	0.3
Welfare gain of bailouts	–1.9	
High $\bar{A}$ ($\bar{A} = 0.30$)		
Default frequency	0.6	0.4
Sovereign spread		
mean	0.8	0.0
standard deviation	1.0	0.9
corr(GDP, spread)	–0.2	0.0
Debt/GDP	10.5	19.8
Mean lending rate	0.0	0.8
Welfare gain of bailouts	–0.8	

Units: percent (except for corr. coeff.).

2. **Financial shock shape,** σ_ε. Due to the nonlinear effects of financial shocks on the real economy as discussed in Section 4.5, the larger the volatility of the potential loss to banking capital, the higher the need for bailouts. Indeed, Table C.8 shows that higher volatilities are associated with a higher default frequency, and higher and more volatile spreads. This is because the model generates a stronger 'diabolic loop.' The increase in the potential loss to banking capital creates higher incentives for the government to borrow to finance the bailouts, which increases the risk of default. Even though the welfare loss from access to bailouts is slightly smaller with higher values for σ_ε, we still find that banning bailouts altogether is optimal from an ex ante point of view.

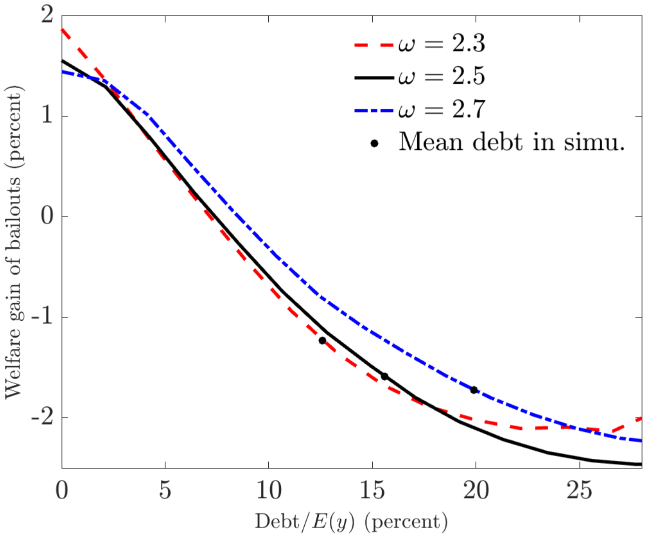
Table C.8: Sensitivity to σ_ε

	Baseline model	Model without bailouts
Low σ_ε ($\sigma_\varepsilon = 3.76$)		
Default frequency	0.4	0.3
Sovereign spread		
mean	0.6	0.4
standard deviation	0.5	0.4
corr(GDP, spread)	–0.4	–0.4
Debt/GDP	22.3	34.0
Mean lending rate	0.0	0.2
Welfare gain of bailouts	-1.8	
High σ_ε ($\sigma_\varepsilon = 4.76$)		
Default frequency	0.7	0.4
Sovereign spread		
mean	1.0	0.5
standard deviation	1.0	0.7
corr(GDP, spread)	–0.3	–0.3
Debt/GDP	12.2	22.2
Mean lending rate	0.0	0.3
Welfare gain of bailouts	–1.3	

Units: percent (except for corr. coeff.).

3. **Frisch elasticity,** $1/(\omega - 1)$. Our baseline calibration sets the wage elasticity of labor supply to an intermediate value from within the range of estimates in the literature. We have argued that the diabolic loop, which bailouts create, is costly (in part) because distortionary labor taxes (and new debt) are used to finance those bailouts. Therefore, one might expect that for a low elasticity, this distortion will be smaller and it could moderate or even overturn the baseline welfare results. Figure C.5 shows that all else equal, and, in particular holding fixed the level of debt, indeed the welfare loss from bailouts is smaller when ω is higher (i.e. the Frisch elasticity is lower). Note that access to bailouts still results in a welfare loss.

Figure C.5: Welfare gains with different ω values.



Note: the graph shows the welfare gain of having access to bailouts as a function of the debt level, for different values of the Frisch elasticity parameter (ω). The black dots denote the mean debt levels in the respective economies. The figure is constructed assuming average values for TFP and ε.

Furthermore, as shown in Figure 12 and Figure C.5, the welfare gains of bailouts are decreasing in the debt level. The solid dots in Figure C.5 show the total effect that changes in ω have on welfare: Holding debt levels fixed, a higher ω (i.e. lower elasticity) reduces the welfare loss from bailouts, but at the same time, increases the debt capacity of the economy with bailouts, thus increasing the welfare loss from bailouts. Table C.9 (and the solid dots in Figure C.5) shows that the second effect dominates.

Table C.9: Sensitivity to ω

	Baseline model	Model without bailouts
High Frisch Elasticity ($\omega = 2.3$)		
Default frequency	0.7	0.5
Sovereign spread		
mean	0.9	0.6
standard deviation	1.1	0.8
corr(GDP, spread)	–0.3	–0.3
Debt/GDP	12.6	22.8
Mean lending rate	0.0	3.0
Welfare gain of bailouts	–1.4	
Low Frisch Elasticity ($\omega = 2.7$)		
Default frequency	0.6	0.3
Sovereign spread		
mean	0.8	0.5
standard deviation	0.6	0.5
corr(GDP, spread)	–0.4	–0.3
Debt/GDP	19.9	30.5
Mean lending rate	0.0	0.2
Welfare gain of bailouts	–1.8	

Units: percent (except for corr. coeff.).

4. **Household discount parameter,** β. Since the government represents the preferences of households, a lower discount parameter (corresponding to less patience) results in an increase in default frequencies, as well as spreads (Table C.10). There is also a slight increase in the amount of debt in the baseline model. The result that the no-bailout economy features a lower likelihood of default, lower and less volatile spreads, and higher welfare is robust to these alternative values.

Table C.10: Sensitivity to β

	Baseline model	Model without bailouts
Low β ($\beta = 0.76$)		
Default frequency	0.9	0.5
Sovereign spread		
mean	1.1	0.7
standard deviation	1.1	0.7
corr(GDP, spread)	–0.3	–0.4
Debt/GDP	16.0	26.8
Mean lending rate	0.0	0.4
Welfare gain of bailouts	–2.3	
High β ($\beta = 0.86$)		
Default frequency	0.3	0.2
Sovereign spread		
mean	0.5	0.4
standard deviation	0.6	0.5
corr(GDP, spread)	–0.3	–0.5
Debt/GDP	15.3	26.4
Mean lending rate	0.0	0.1
Welfare gain of bailouts	–1.0	

Units: percent (except for corr. coeff.).

5. **Working capital constraint,** γ. The working capital constraint parameter determines the amount of working capital loans that firms demand. Higher values increase the demand for loans, which increases the loans' interest rate. With higher values of γ, we find that the government responds by injecting more liquidity into the financial system by increasing debt, as shown in Table C.11. The ex ante welfare loss from bailouts is robust to alternative values of γ.

Table C.11: Sensitivity to γ

	Baseline model	Model without bailouts
Low γ ($\gamma = 0.49$)		
Default frequency	0.7	0.4
Sovereign spread		
mean	0.9	0.5
standard deviation	1.0	0.7
corr(GDP, spread)	–0.1	–0.2
Debt/GDP	12.2	21.9
Mean lending rate	0.0	0.3
Welfare gain of bailouts	–1.3	
High γ ($\gamma = 0.55$)		
Default frequency	0.6	0.4
Sovereign spread		
mean	0.8	0.5
standard deviation	0.7	0.5
corr(GDP, spread)	–0.5	–0.4
Debt/GDP	22.9	33.4
Mean lending rate	0.0	0.3
Welfare gain of bailouts	–1.9	

Units: percent (except for corr. coeff.).

6. **Probability of bank capital shock,** π. To examine the role of the bank capital shock in our results, we set π to 1 percent and 10 percent. In our model, the government promises bailout guarantees in the expectation of a banking crisis and thus, when the probability of having a banking crisis increases, the government becomes more reluctant to promise guarantees upfront knowing that the financing of that bailout will be costly once the shock hits. As shown in Table C.12, we find larger welfare losses from access to bailouts when π increases.

Table C.12: Sensitivity to π

	Baseline model	Model without bailouts
Low π ($\pi = 0.01$)		
Default frequency	0.5	0.3
Sovereign spread		
mean	0.7	0.5
standard deviation	0.7	0.5
corr(GDP, spread)	–0.3	–0.3
Debt/GDP	15.6	26.8
Mean lending rate	0.0	0.2
Welfare gain of bailouts	–1.4	
High π ($\pi = 0.10$)		
Default frequency	0.6	0.3
Sovereign spread		
mean	0.8	0.5
standard deviation	0.8	0.5
corr(GDP, spread)	–0.3	–0.3
Debt/GDP	16.6	26.9
Mean lending rate	0.0	0.2
Welfare gain of bailouts	–1.7	

Units: percent (except for corr. coeff.).

7. **Labor share,** α. Similar to the working capital constraint parameter, γ, the labor share parameter determines the amount of working capital loans demanded by firms. As such, changes in α have similar properties as changes in γ. As shown in Table C.13, the ex ante welfare losses of bailouts increase with higher α.

Table C.13: Sensitivity to α

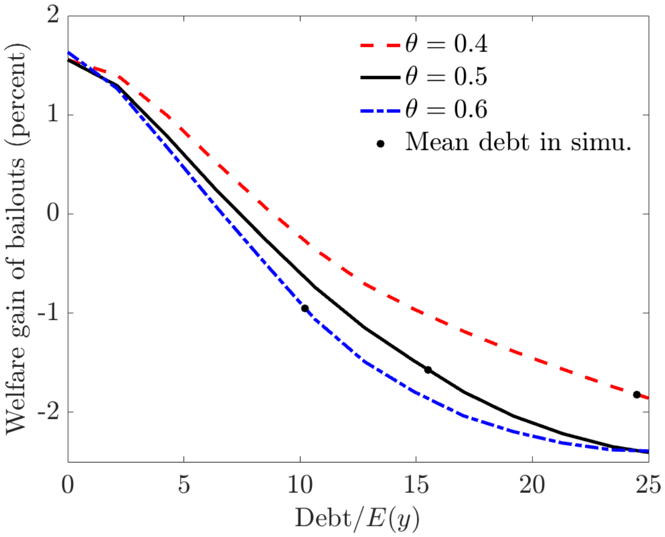
	Baseline model	Model without bailouts
Low α ($\alpha = 0.65$)		
Default frequency	0.6	0.5
Sovereign spread		
mean	0.8	0.1
standard deviation	1.1	1.0
corr(GDP, spread)	–0.3	–0.1
Debt/GDP	10.1	18.6
Mean lending rate	0.0	0.7
Welfare gain of bailouts	–0.9	
High α ($\alpha = 0.75$)		
Default frequency	0.6	0.4
Sovereign spread		
mean	0.8	0.5
standard deviation	0.7	0.5
corr(GDP, spread)	–0.6	–0.5
Debt/GDP	28.1	38.7
Mean lending rate	0.1	0.3
Welfare gain of bailouts	–1.9	

Units: percent (except for corr. coeff.).

8. **Probability of financial redemption,** θ. As we explained in Section 5, the ability to issue bailouts affects the costs of defaults, and these are made of two parts. The *first part* materializes in the periods in which the government is excluded, and is identical for economies with and without bailouts. The *second part* comes once the government has reentered financial markets: the reentry occurs with zero debt, which depresses private credit and output. We can interpret the reduced output level upon reentry as another component of the costs of defaults. This second part of the cost of default is lower in the bailout economy because it can prop up liquidity using bailouts.

   These two parts to the cost of default and how they are affected by the access to bailouts interact with the reentry probability. The higher the reentry probability (θ), the more relevant the second part of the default costs, and therefore the more important the effect of bailouts on default costs. Under a higher θ, the relatively lower default costs in the bailout economy are reduced even further, leading to lower debt capacity and welfare. Therefore, other things equal (in particular, for a given level of debt), a higher θ is associated with a lower welfare gain of bailouts. Figure C.6 shows this result.[33]

   Figure C.6: Welfare gains of bailout: the role of θ.

   Note: the graph shows the welfare gain of having access to bailouts as a function of the debt level, for different values of the reentry probability (θ). The black dots denote the mean debt levels in the respective economies. The figure is constructed assuming average values for TFP and ε.

   As shown in Figure 12, the welfare gains of bailouts are decreasing in the debt level. Figure C.6 also shows this, for different values of θ. The solid dots in Figure C.6 show the total effect that changes in θ have on welfare: A higher θ reduces the default costs

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[33] Note that there is no recalibration involved in the construction of this figure.

of the bailout economy (lowering the welfare gain of bailouts, holding debt levels fixed), which endogenously leads to a lower debt level (increasing the welfare gain of bailouts). Table C.14 (as well as the dots in Figure C.6) shows that the second effect dominates.

Table C.14: Sensitivity to θ

	Baseline model	Model without bailouts
Low θ ($\theta = 0.40$)		
Default frequency	0.4	0.2
Sovereign spread		
mean	0.6	0.4
standard deviation	0.5	0.4
corr(GDP, spread)	–0.5	–0.4
Debt/GDP	24.5	34.6
Mean lending rate	0.0	0.2
Welfare gain of bailouts	–1.7	
High θ ($\theta = 0.60$)		
Default frequency	0.8	0.4
Sovereign spread		
mean	1.0	0.3
standard deviation	1.3	0.8
corr(GDP, spread)	–0.2	–0.1
Debt/GDP	10.2	21.8
Mean lending rate	0.0	0.6
Welfare gain of bailouts	–1.1	

Units: percent (except for corr. coeff.).

D Computational Appendix

The model is solved using value function iteration with a discrete state space. We solve for the equilibrium of the finite-horizon version of our economy, increasing the number of periods of the finite-horizon economy until value functions and bond prices for the first and second periods of this economy are sufficiently close. Then, the first-period equilibrium objects are used as the infinite-horizon-economy equilibrium objects.

Algorithm. First, we specify initial values of repayment (V_0^R) and default (V_0^D) as the values at the last period of the finite-horizon version of the model. That is, for a point (b, s, A) in the state space, we set

$$\begin{aligned} V_{(0)}^R(b,s) &= \mathbf{E}_A\left[u(c^*_{\text{LP}}, n^*_{\text{LP}})\right] \\ V_{(0)}^D(b,s) &= \mathbf{E}_A\left[u(c^*_{\text{def; LP}}, n^*_{\text{def; LP}})\right] \end{aligned}$$

where (c^*_{LP}, n^*_{LP}) are the optimal consumption and labor decisions in the last-period of the finite horizon economy (hence the LP subscript). A similar interpretation applies for ($c^*_{\text{def; LP}}$, $n^*_{\text{def; LP}}$), but under default. From these initial guesses, we can derive an initial guess for the default decision (being 1 if $V_{(0)}^D > V_{(0)}^R$ and 0 otherwise). We also compute and retain the equilibrium values of r_{LP}, both under repayment and default: These values are needed to compute the bond price.

Second, using these initial values, we solve for the problem stated in (20)–(22) for each point in our discrete state space.

To solve the problem under default, we compute (c^*_{def}, n^*_{def}, r^*_{def}) following the equilibrium conditions in the private sector. With these allocations and prices we can get the new guess for the value of default, $V_{(1)}^D$.

To solve the problem under repayment we do the following for each combination (b, s):

1. Propose a candidate bailout, T_{c}.

2. Given (b, s, T_{c}) solve for the optimal borrowing level by searching over the debt grid and selecting the level that maximizes $V^R(\cdot; T_{\text{c}})$. Denote this level, b'_{c}. Note that this step involves solving the equilibrium of the private sector for each possible point in the state space and each given candidate transfer T_{c}.

3. From all the candidate values of T_{c} (and associated b'_{c}), choose the one that maximizes V^R. This is done taking expectations over the possible realization of A: $\overline{A}$ with probability $1-\pi$ or $(1-\varepsilon)\overline{A}$ with probability π.

4. Finally, update the guess for the value of repayment, $V^R_{(1)}$.

From the process above we also recover (among other quantities and prices) r^*, which is the equilibrium loan rate. This rate needs to be saved in order to compute the bond price (according to equation (19)) in subsequent iterations.

Third, we evaluate whether the maximum absolute deviation between the new and previous continuation values is below a give tolerance level. If it is, a solution has been found. If it is not, we repeat the optimization exercise using the new continuation values $V^R_{(1)}$ and $V^D_{(1)}$ to compute the expected value function at each grid point and to derive default probabilities that affect the price faced by the borrower. We repeat the procedure until the maximum absolute deviation between the new and previous continuation values is below a given tolerance level.

Implementation. We use the Tauchen method to discretize the TFP shocks in 25 states. We discretize the ε shocks into four states in a one-sided application of the Tauchen method.

We use 50 evenly distributed grid points for debt. The debt grid is: $b \in [0, 0.80]$. Recall that GDP is endogenous in our model: In the benchmark calibration, mean annual GDP is roughly 0.77 which implies our debt grid covers more than 100 percent of annual GDP.

The simulations presented in the main body of the paper come from the algorithm described in this appendix and allowing for the bailout to take any of 50 evenly distributed grid points ranging from zero to full coverage of the damage to the banking sector capital, i.e. $T_{\mathrm{c}} \in [0, \varepsilon\overline{A}]$.